Tappi

E JOURNAL OF THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

JUNE 1961

VOLUME 44 • NUMBER 6

From S. W. Hooper: a time-and-pressure bark dehydration method

REC'D JUN 26 1961

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A wet sponge is not just squashed, it is squeezed. Similarly two factors — time and pressure — are needed to dehydrate bark. This is the principle of the Cowan bark press, which applies sustained and progressive pressure to turn wet bark into combustible material. An oil hydraulic system regulates a feed plunger and pressing beam operating in a chamber with three force-drainer sides.

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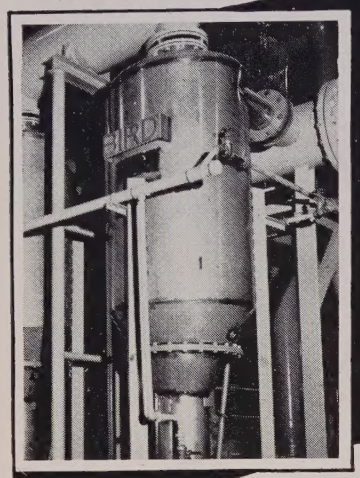

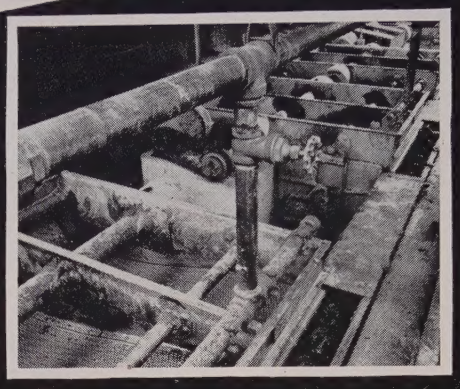

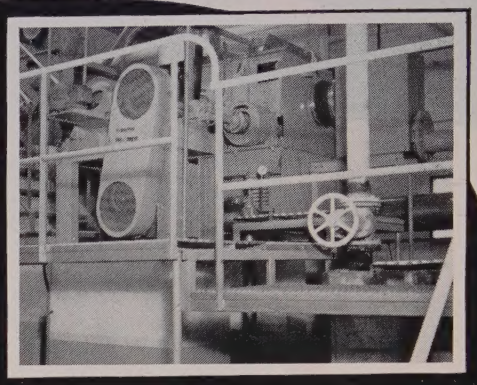

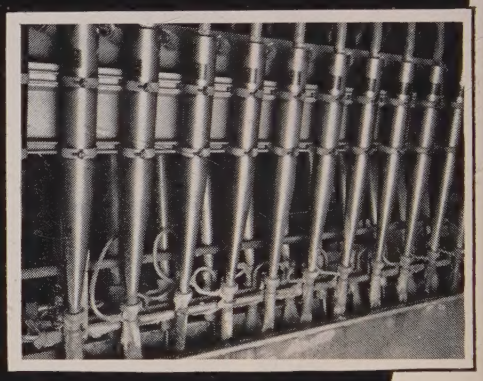

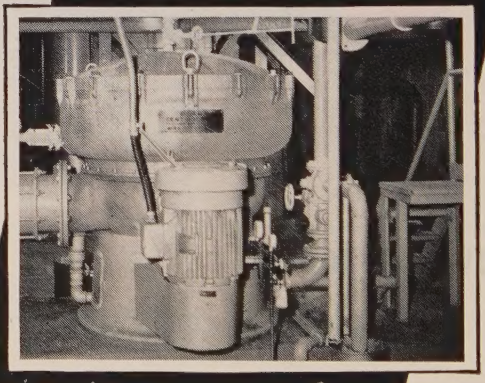

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Eleventh Corrugated Containers Conference
St. Francis Hotel, San Francisco, Calif.
Sept. 6–8, 1961

Fourth International Mechanical Pulping Conference
(Tech. Sect., CPPA-TAPPI)
Edgewater Beach Hotel, Chicago, Ill.
Sept. 19–21, 1961

Sixth Deinking Conference
Hotel Harris, Kalamazoo, Mich.
Oct. 4–6, 1961

Sixteenth Plastics-Paper Conference
French Lick Sheraton Hotel,
French Lick, Ind.
Oct. 9–11, 1961

Sixteenth Engineering Conference
Shoreham Hotel, Washington, D. C.
Oct. 15–19, 1961

Fifteenth Alkaline Pulping Conference
Rice Hotel, Houston, Tex.
Nov. 1–3, 1961

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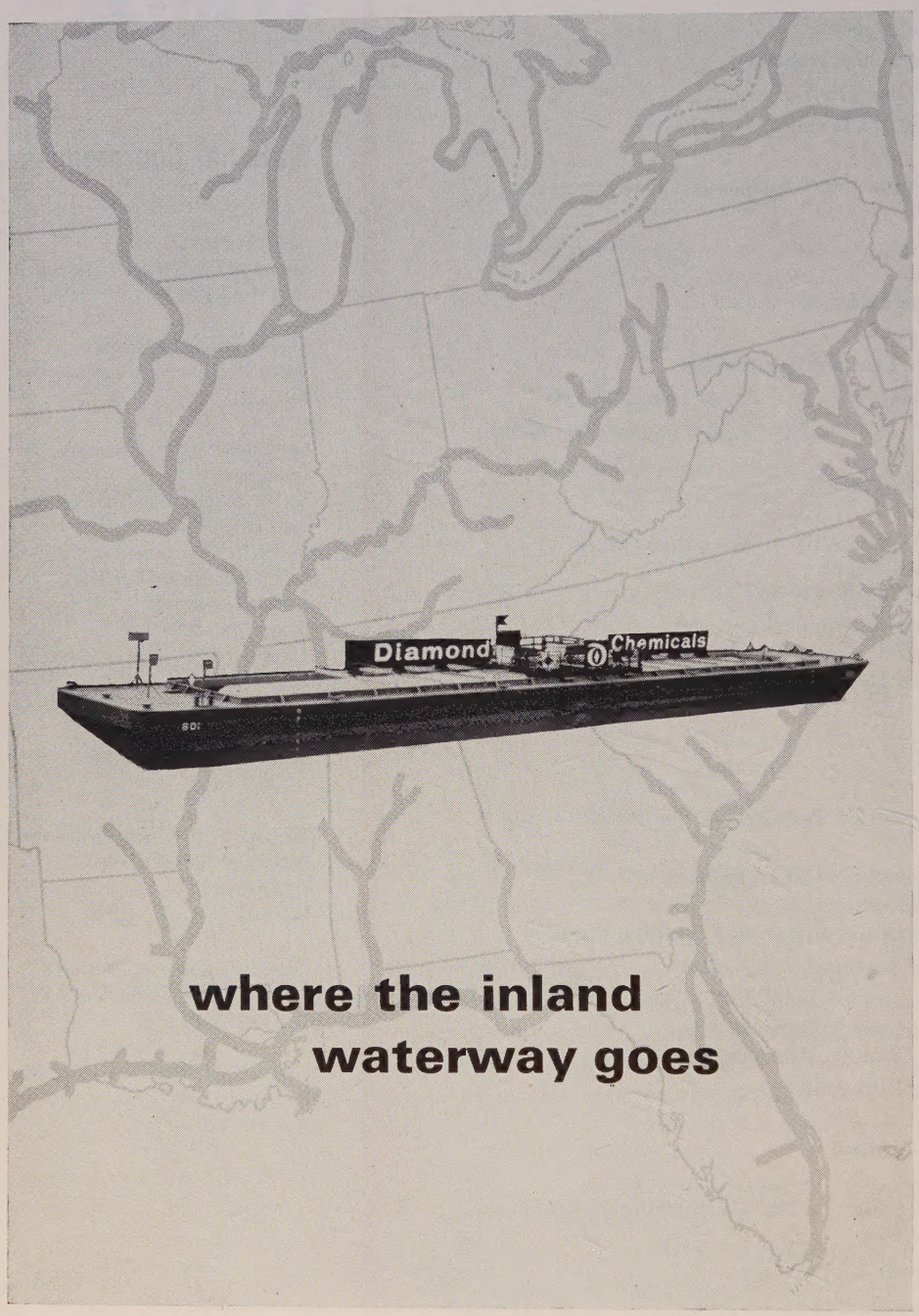

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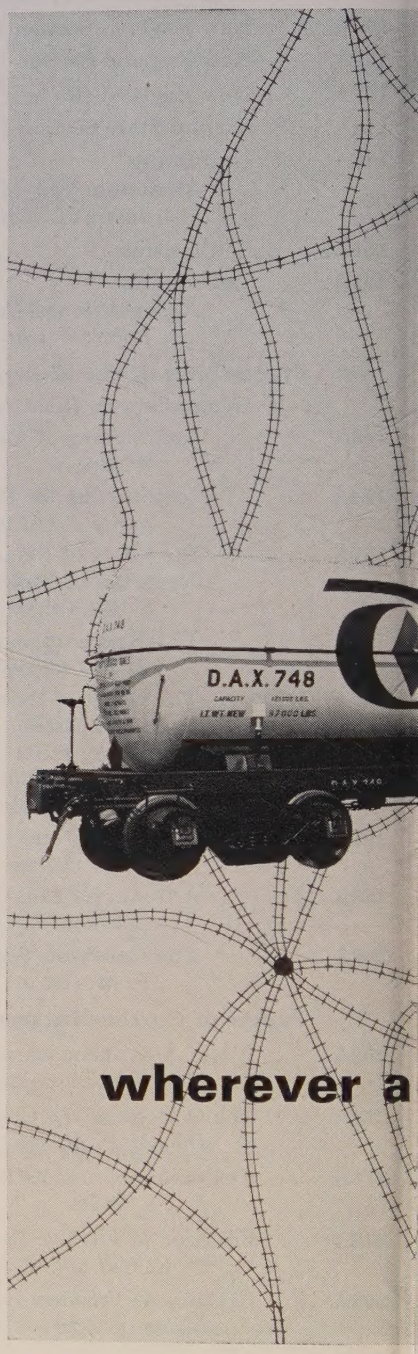

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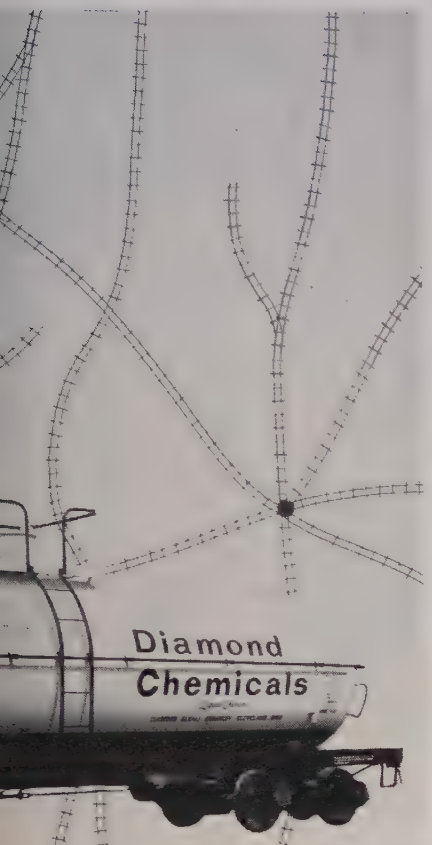

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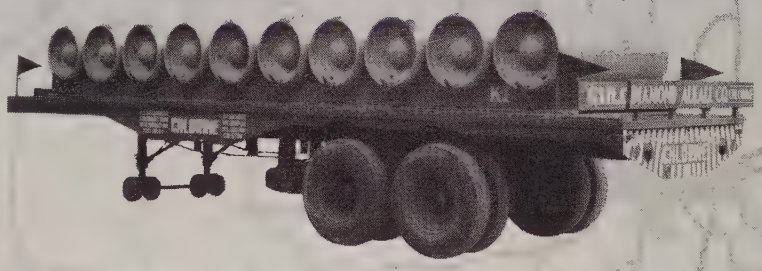

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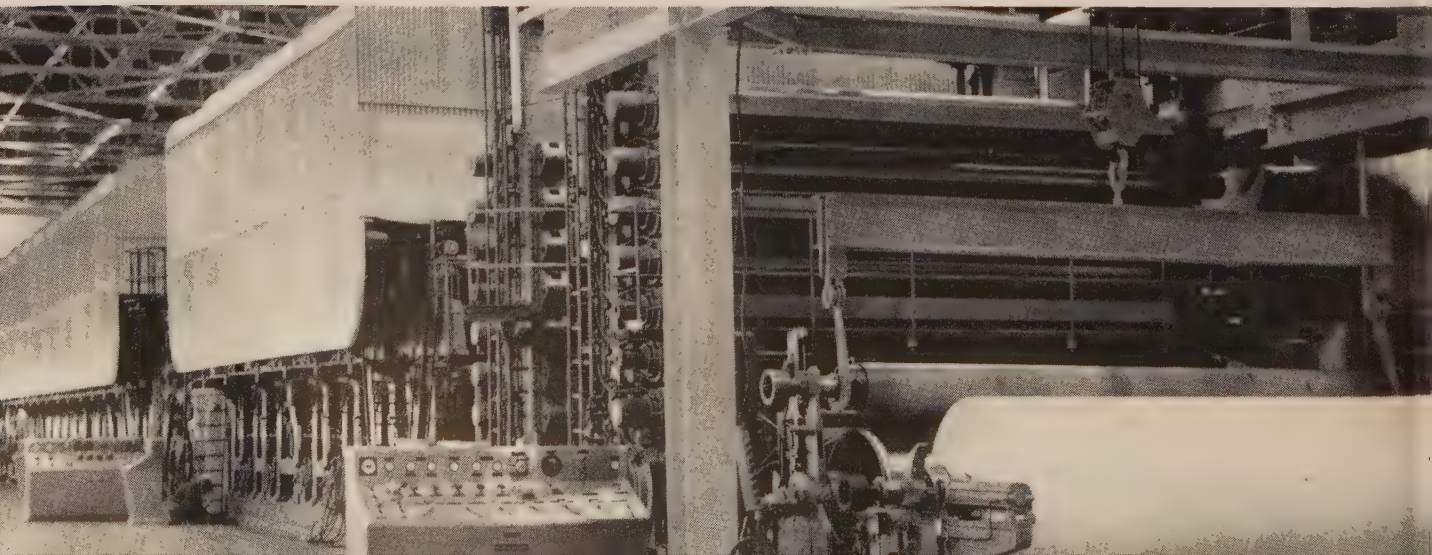

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SPRING TENSION USED [X] A [ ] B

PRINTING VELOCITY, FT./MIN. AT 35 Kg. PRINTING PRESSURE

A TENSION	B TENSION
100	100
200	200
300	300
400	400
	500
	600

DOW LATEX 630 COATING
Picking Velocity: 290 Ft./Min.

COMPETITIVE LATEX COATING
Picking Velocity: 150 Ft./Min.

PROVEN commercially... greater pick resistance with DOW LATEX 630

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The two strips on the right coated with a competitive latex represent the performance of the "standard" grade. The two strips on the left represent the performance of that grade with Dow Latex 630 replacing the competitive latex in the coating.

In this test, Number 6 ink was used, and "A" spring tension. The test strips show that average pick velocity of strips with the competitive latex coating was 150 ft. per minute. But strips coated with Dow Latex 630 showed an average pick velocity of 290 ft. per minute . . . also note the reduction in bodystock splitting and the "blacker" black of the ink with the Dow Latex 630 coating.

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What Management Wants to Know

ARTHUR W. PLUMMER

ONE of the world's most intriguing, most complex, and inexact subjects, "What Management Wants to Know" goes from A to Z and back again with any number of alphabetical variations. Let me tell you, therefore, how happy I am to be speaking on the subject, "What Management Wants to Know" rather than the subject, "How to *Answer* What Management Wants to Know."

Seriously, where does one begin to discuss "What Management Wants to Know"? We might start with the dramatic and breathtaking futures of missilery and space adventure and their certain influence on every management represented here today. We could take the broad and worldly view since management certainly looks to expanding foreign trade and is concerned with the threat of Communism or other -isms to the free world. Or the hemispheric view wherein management must ponder the changing social and economic patterns in the United States, Canada, Mexico, and Latin America, not to mention the "Castrotrophic" implications of Cuba. Regardless of the arena, however, serious management wants to run a *successful* business. It seems logical, therefore, to start with *profit* as our touchdown and to examine the plays and coach's strategy leading to it.

Reduced to its simplest business terms, "What Management Wants to Know" is how to make a reasonable profit by developing, manufacturing, and selling products that fill consumers' needs. Profit is the first responsibility of management and the result of "blood, sweat, tears" and bewilderingly complex operations that management must manage. What management knows or learns and how, thereafter, it provides leadership, organization, facilities, and enthusiasm will determine the final profit level for the company.

Instead of profit, many companies favor the use of return on investment, where possible, as more meaningful. Determining this, of course, is easier said than done when dealing with improvements in current products. However, it is usually not so difficult when you are dealing with wholly new products. You will note, however, that I use the term profit hereafter. This is more convenient and, furthermore, in the definitive sense, I would rather talk about "profitable" instead of "returnable" products.

What can management learn and apply, therefore, that will lead to this desirable climax? Like any good football coach worrying about next year's team, progressive management will ask hundreds of related questions about short range and long-pull growth of the enterprise. These can be distilled into four, however, which are of prime importance:

1. What sort of company are we now and what should we become?
2. What should be our product policies?
3. How is our credit in the money market and what can we do to improve it?
4. What kind of an organization do we have and how should we change it gradually to fit future plans?

I would like to discuss these with you.

1. *What Sort of Company Are We and What Should We Become?* Taking the simple things first—Are we big or are we small? If we haven't made *Fortune's* First 500 Corporations, we're small—if we have there may *still* be some question.

To what markets do we cater? Mass market at low profit, or select market with creamy margins? Consumer market, or industrial market? Are we still making buggy wheels and happy with it, or do we have the courage to retool and make nose cones? After all, both have circular sections.

What part have we played in raising the living standards of the United States and the world? Are we strongest in durables, or nondurables? Do we make the softest and silkiest sanitary tissue, or turn out atomic bombs? Should we strive for ever higher standards of living and culture for our customers? Or should we contribute further to decline of human intellect with wrist TV sets that tune only to Quick Draw McGraw?

These are specimens, half-serious, half-in-jest, to remind us what we might become whatever we are now. Whether serious, or in jest, management *must* know enough to set the corporate goals 10 to 15 years hence and choose the thorny paths to meet them.

In doing so, management surely would like to know if we are sales oriented and why? Or have we become known as a progressive, research-minded company whose products sell easily and are trusted widely? What corporate image *have* we created and how can we build on it? How important *are* new products in future planning? Moderate scanning of claims by long established companies reveals that 30 to 70% of their present volume is in products not in existence 15 years ago. Managements who do not know this *must* be convinced.

Let's assume management is convinced. It has made the momentous decision—we want to be bigger. But how much bigger? Simple arithmetic, a constant market share and certain facts of life guarantee that our present products should grow—about 3% per year. Of course, if we are not content with our modest 75% of the market and wish to be greedy, we must loosen our 15-year belt accordingly.

Granted that we can add two and two and somehow get five, can we also add in the uncertainty of future markets and change in consumer habits? I think we can, in three ways, namely: (1) by increasing the number of long range planners, (2) by uttering a prayer that management has a rather large and elongated crystal ball with a 15-year hairline division scale, and (3) by organizing a dynamic New Products Department.

ARTHUR W. PLUMMER, Chief Industrial Engineer, S. D. Warren Co., Cumberland Mills, Me.

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There will always be *some* crystal balling, of course, but the New Products Department can put numbers on the scale.

By the way, a spanking-new Products Department can render management a great service within weeks of its founding. To become bigger, management has to dig deep in corporate coffers, or leave an IOU in pockets flush with venture money. How much will they need in the next 15 years? They can *guess*, of course, or set the astronomical fund arbitrarily but with two or three new product ideas just hatching you can give them some guidance in their planning.

And, gentlemen, it is imperative in this game that the New Products Department and management maintain a two-way, continuous exchange of information. To have meaning in any long-range planning, the specifics of departmental programs must be measured against broad corporate policies and objectives. My reply to question 4 will point out a few possibilities.

2. *What Should Be Our Product Policies?* At the risk of sounding like a TV commercial, I will say that this is a mighty meaty question. Of course, it is never asked as one question; it always appears as "What should we do to our *present* products?" and "What *other* products should we make?" Management will always want to know the answers to both and may make some unhappy and unilateral decisions unless we exercise bold and imaginative judgment. That is, it should appear as dynamic and imaginative judgment even though it is forged from months of routine market searching and inquiry.

And, of course, we can always embrace the obsolescence theory for our general products policies.

How often have you heard proclaimed with rhetorical emphasis, "We obsolete *our* products before someone else does!" I shall define this as paternal obsolescence—or the subtle art of converting model Mark 199 slightly to Mark 200—then chewing your nails while the customers you hoped to gain are offset by those you are certain to lose. Paternal obsolescence is philosophically sound for several reasons, not the least of which is an active research department with a healthy budget that it promotes. But the Mark 199 should be converted all the way to Mark 250 and thus, retain and gain new markets. In fact, this is the only sound way to compete with external obsolescence—which is the not so gentle art practiced by young upstarts, or canny old-timers in sneaking your market from under your very nose.

Seriously, though, we all know that profitable present products must be kept strong in the marketplace—else there could be no new product entrees from our enterprise. I emphasize, however, that lasting market gains are made with real and lasting product improvements, not by advertisable "gimmicks." This will be shockingly true in the sixties as the present new product rivulet grows to a raging torrent.

Now, what about other products we should make? Where do we start? How do we decide what to make? Are we willing to make and sell any product that will give a good return, or should we withdraw and nurture our current line and corporate image? Should we seek to fill an existing consumer need? Or can we afford the long and arduous task of creating something wholly new in the consumer's life and then educate him to consider it indispensable?

You recall, perhaps, that 12 to 15 years ago DDT became common in our household vocabulary. Today, in our corporate vocabularies, we have another DDT. This time it is not a tongue-twisting chemical name but rather a thought provoking question, "Diversification—Defeat or Triumph?"

Used with caution and good sense this later-day DDT can, like its predecessor, be of great value in our corporate life. Managements everywhere have and will continue to ask, "*Should* we diversify?" Judging from apparent evidence, I would shout an unqualified "Yes!" But it must be done cautiously. What we should do I would ask of the New Products Department. *How* we do it depends on the special skills we have.

Any management, or New Products Department will ask "What can *we* do *best?*" To paraphrase a famous quotation, they would then ask, "Will our bestest get us there fustest with the mostest for the leastest?" If management knows the answer is yes, you will have a very busy New Products Department rounding out product lines and exploring entirely new products that will converge toward your top skills and existing equipment.

However, if management dislikes its own cooking, so to speak, it may decide to have dinner at the home of a friend. In other words, merge with, or acquire what it needs.

The merger era, now of age, sees higher price tags on such deals—so management wants to know how to acquire the needs in other ways. The New Products Department, working with management, can have a most interesting time providing an answer. For example, should we form a third company, jointly owned with a large established company in another field? Or should we look for patents we can license, or buy outright? Or should we take into the fold a "hungry" entrepreneur who has a cracker-jack of an idea but who is barely outside the backyard garage? The answer yields after prodigious soul-searching, market-searching and finally crystal ball gazing.

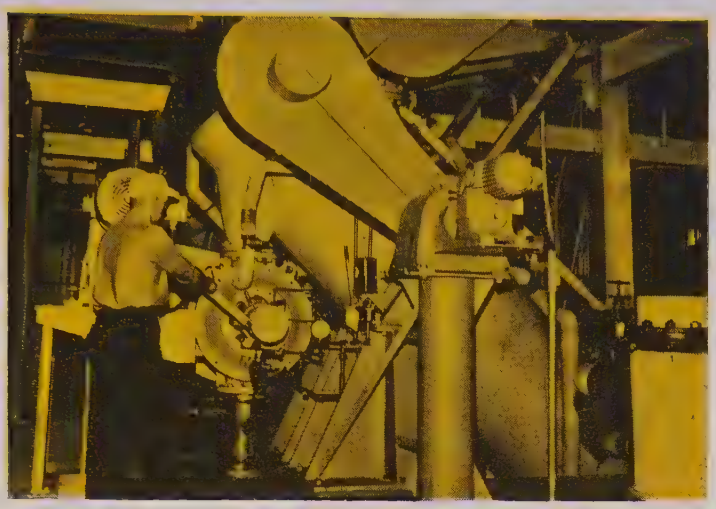
3. *How Is Our Credit in the Money Market and What Can We Do to Improve It?* Progressive management will always be searching for new capital money. With today's tax structure, reinvested earnings are usually not enough. So where can new money be found? The answer is, of course, from several sources if your earnings and dividend records stand high and you have rolled up a string of conspicuous successes. But how deftly and, of course, how justifiably the money-lenders will shrug you off if you bear the stigma of falling profits, dwindling market shares, or irregular dividends.

And so, management wants to know how, under any circumstances, to look like a rose, smell like a rose and whenever possible to *be* a rose. Those of you who have helped write, or design, corporate brochures for the care and feeding of bankers, or have escorted prominent bankers through your research laboratories, know that this is serious business. And it will ever be so in our capitalistic, expansionistic economy.

Mark it well, then, that corporate credit is a sensitive subject to management, and do what you can in research, engineering, sales, etc. to *guarantee* that your management is *really* a rose.

4. *What Kind of an Organization Do We Have and How Should We Change It Gradually to Fit Future Plans?* I have saved this question until last because

3 Types of Automatic Digesters To Increase Mill Capacity

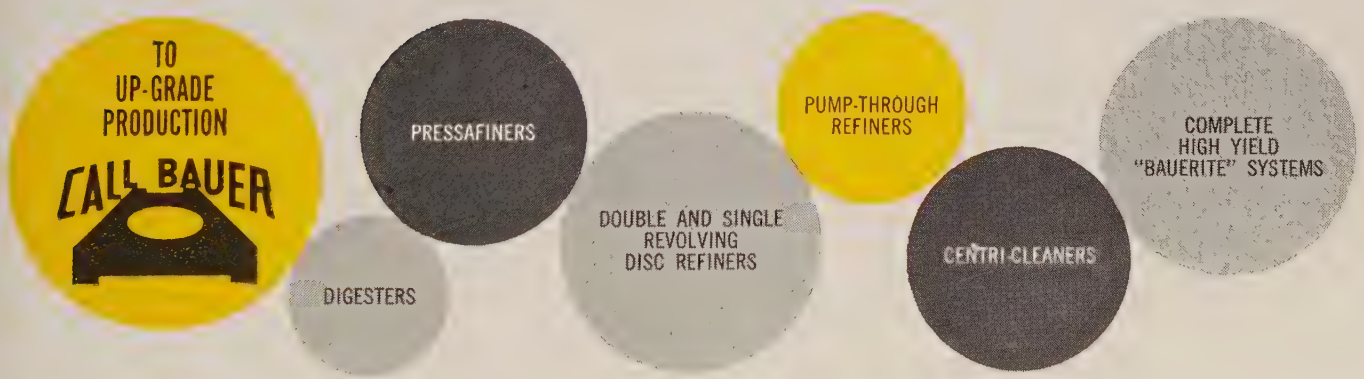


M & D Continuous Digester.
Note inlet and discharge valve are on same floor level.

M & D DIGESTER (continuous) — Inclined tube type... makes controlled continuous digestion of chips practical. Suitable for wide variety of end products as units are engineered to your requirements. Completely automatic; reduces labor costs, improves uniformity. 90% of unit can be outdoors.

RAPID CYCLE DIGESTER (batch) — Fast, automatically controlled batch cooking... high temperatures and pressures (up to 300 psi) reduce cooking time to minutes. For any type pulp and flexibility in procedures... ideal for multiple treatment—presteam, impregnate, vapor phase. Compact... easy to install. Stainless steel... no lining... long life.

GRENCO DIGESTER (continuous, vapor phase) — Most economical for vapor phase method of preparing wood chips... automatically controlled... simple in design. To increase output units can be "stacked." Automatic... continuous feeding and discharging... minimum space requirement... relatively light weight.



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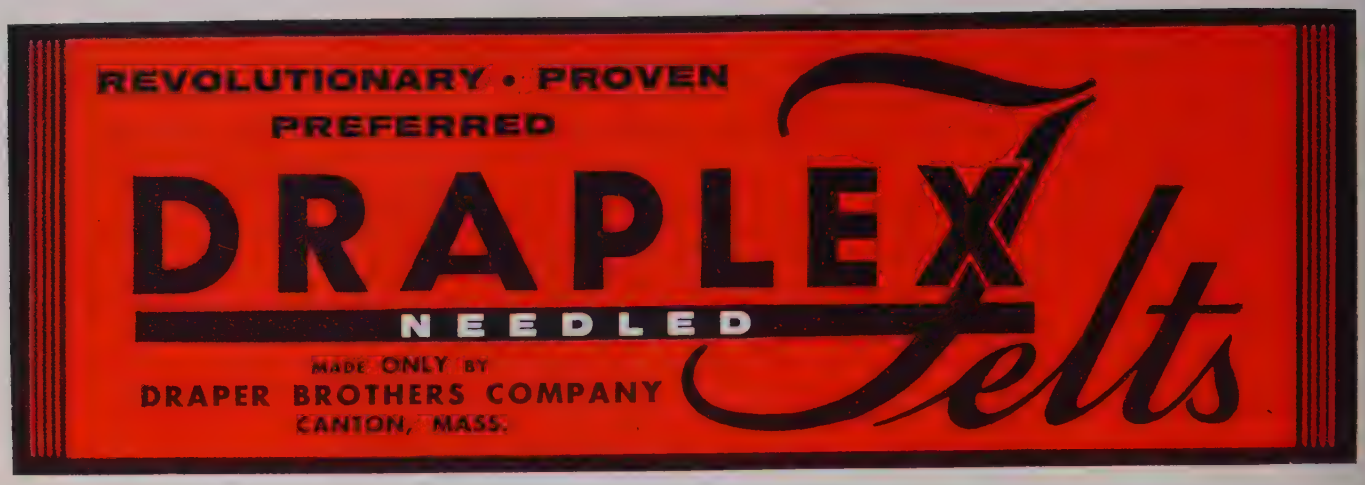

almost everything that management wants to know is answered by an internal organization. My wife, with obvious pleasure, tells me that women make all the small decisions like rearing the children, selling or buying the house, having the car fixed, and calming an ulcerous husband while men discuss the big decisions, such as foreign affairs, shooting a man-bearing rocket to Mars next month, how to end World War III before it starts, and finding Jules Verne's path to the center of the Earth. If she is right, and I will not publicly admit it, then woman to man is what organization is to management—a fundamental and indispensable support. I would say forthrightly, therefore, that management's greatest need for skill and knowledge lies in organizing the people and communications of an enterprise.

It is with consummate skill indeed that the New Product Department is organized and staffed. Drawing varied skills from all points of the corporate compass and knitting them into an integrated, smooth running team is a masterful stroke of management. Yet, it must be done for management to move toward the goals in questions 1, 2, and 3.

And now I want to discuss a case history of planning for new products—one into which I was drawn reluctantly. But once there I considered it one of my rare industrial experiences.

It all began a few years ago when management wanted to know why our large research organization failed to turn out more new products. To get the answer, R & D management turned loose a "gad-flyish" staff assistant to survey the first echelon supervisors. His report offered convincing proof that R & D was working on several new products—when they could find the time. It was clear that even the "sacred" 10% of a scientist's time, set aside for exploration, was not being used. It was equally clear that the new products record was poor and would continue to be unless R & D could be isolated from daily pressures.

Then and there, R & D management reacted but it took two years to answer the three questions posed:

1. How can we rapidly get our present new product ideas into the market?
2. Where and how do we get other new product ideas?
3. When we get them how can we organize to insure steady progress and a steady flow of products that are profitable?

Fundamentally, two approaches were taken, one preceding the other by a few months. The first was "creativity" and the second a separate, responsibility-isolated New Products Department.

"Creativity" was attractively "faddish" in those days. Managements were almost hypnotized by its alleged power. "Panacea for their problems" was the cry of many practitioners. However, "creativity" was approached cautiously and sensibly by management in my story. They made a thorough study of the recommended techniques, selected one developed by a well-known consulting firm. Probing this one especially, they contracted for consulting time, assigned a company man to join the consultant's group. After many exhausting but stimulating sessions this man felt qualified to form and lead an intercompany group. The history of this "creativity" team is one of management astuteness and careful preparation. Under the guise of recording meeting proceedings, the attitudes and philosophies of many people in the company were tape recorded and painstakingly reviewed. The members were chosen quietly after months of such reviewing. Their selection was announced, their function described, and they were quartered in remodeled office space with their own, adjacent machine shop. The group was organized for a 2-year trial period. I left for greener personal pastures before this period ended. I can report, however, they were generating ideas, using channels and techniques seldom used by an R & D absorbed with other, more mundane tasks.

Realizing that more than idea generation was needed R & D management created a New Products Department to function in three related areas, namely:

Stage 1. Screening and economic evaluation of new product ideas.
Stage 2. Technical appraisal and development
Stage 3. Commercial development

They were wise enough also to create a New Products Evaluation Committee, chairmaned by the vice-president of Research and Development. Sitting on this committee were the chairman of the Board, the president, the executive vice-president, and the vice-president of the Legal Division. The committee secretary was the manager of the New Products Department. I am detailing this committee membership to emphasize my earlier point that communication at a high level is a vital factor in new product planning and development.

Of course, such a council of "chiefs" would be almost helpless without the new products "Indians" to collect

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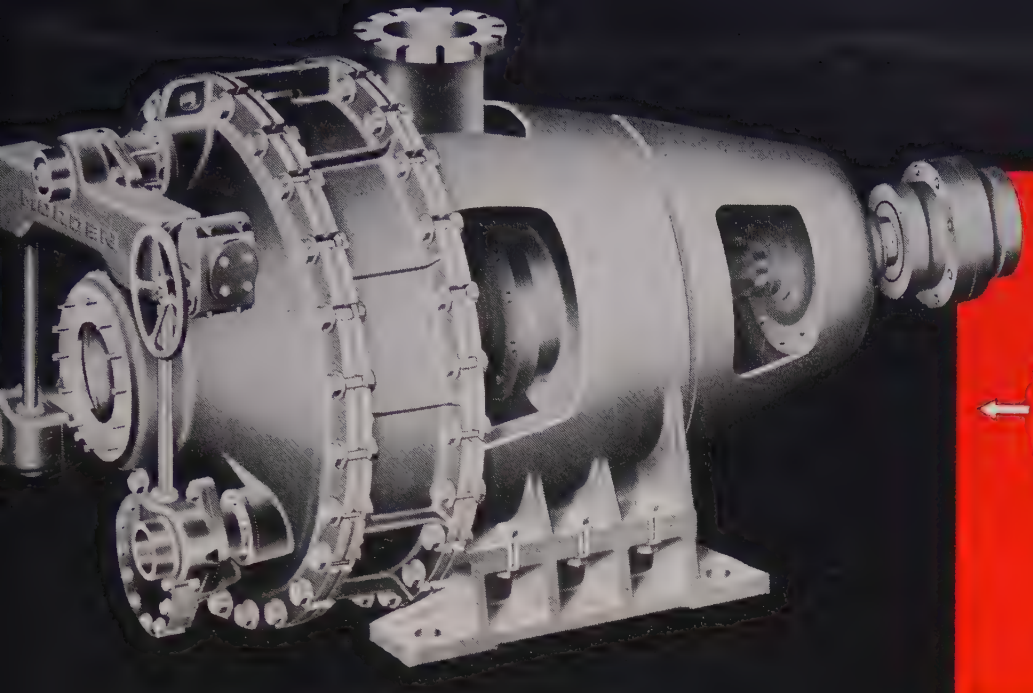

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Here is a truly significant development in stock preparation equipment. Simple flow and filling changes adapt the new DISCO-FINER so that it will either defiber or refine. The self-aligning, semi-conical design of rotor and stator plates eliminates warpage and distortion. The DISCO-FINER is designed to deliver high production without sacrifice of quality, designed to withstand many times the stresses of normal use so that precision is maintained under all conditions.

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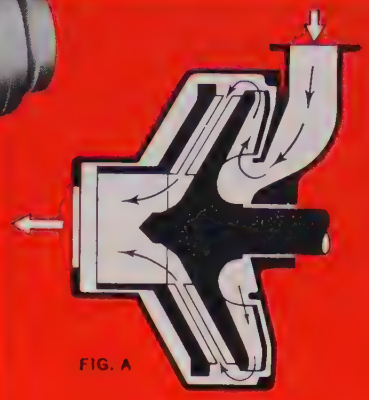

FIG. A

REVERSE FLOW
SELF-PRESSURIZING
FOR REFINING

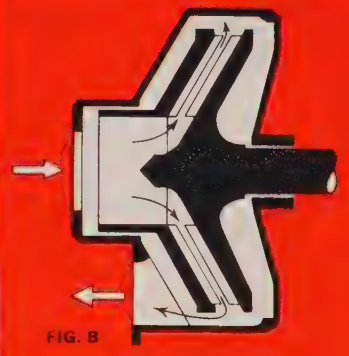

FIG. B

FREE DISCHARGE
FOR DEFIBERING

COMPARE THESE FEATURES WITH THOSE OF ANY OTHER DISC REFINER

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3. 500 to 700 connected horsepower.
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   a. Reverse flow, self-pressurizing for refining. (See Fig. A above)
   b. Free discharge for defibering. (See Fig. B above)
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and pass on what they need to make their policy decisions. Thus, people for the department were selected carefully after many caucuses to bring together the basic skills required.

We had highly capable people in all positions. We also had a high proportion of rugged individualists. This, of course, made life interesting at times. For stage 1 we had an experienced market research man. For stage 2, chemists and chemical engineers. But for stage 3 we formed project teams with several skills either built in or available elsewhere. We set up stage 3 as a small business within the larger corporate one with technical, manufacturing, and sales skills built in. For our other "business" needs we were serviced by corporate groups such as central planning, manufacturing, advertising and promotion, legal (including trademarks and patent handling), budget and cost accounting, and market research. We were budgeted with working capital and operated on a simple system of cost variances designed to show clearly when we reached the break-even time.

Then we were ready to work toward what management wanted to know. We had a few ideas underway, two, in fact, that logically landed in stage 3. But we also had others that came to us wholly unscreened; these dropped into stage 1. Two others fitted nicely in stage 2. So, from the beginning, we were operating all three stages and learning quickly that instead of being sharply divided they overlapped continuously. In a sense this was good for we learned how interdependent we were and management learned to ask some very penetrating questions in all three stages.

We got our new ideas from many sources legion to most of you here. I would refer you to sources suggested by W. E. Kuhn of the Texaco Co. in the November, 1959, issue of *Chemical Engineering Progress.* He did not mention investment bankers and individual inventors, however, both of which can be important. Of course, we refused to hear disclosure of any idea from such sources until a release agreement had been signed and the patent situation mutually understood. I will comment only generally on the steps we took thereafter for they are common to most companies.

Someone has said "The idea is the thing" and so it is. If it is a good idea or poor idea the path is smooth or stops abruptly in the same order. As so often happens, however, the idea is a gray one. Then the market searching, market area selection, price-probing, technical revisions, product engineering and adaptation with the customer are part of the sometimes exhilarating, sometime drudgerous task of crossing the bridge from idea conception to fruition. Cycles of dashed hopes and soaring promise seemed well entrenched in our operations but we enjoyed ourselves tremendously and gained a sense of accomplishment. When one can do this and still make a living, little in the world can equal it.

In conclusion, the Sixties are certain to be a fantastic decade. Management will be hard put to keep abreast of changing markets and the thirst for something new and different. All it needs to know can be supplied by a heads-up, well-organized New Products Department isolated from the daily needs of the business.

Those of you who have not undertaken a New Product Department might well remember that in the single year of 1964 the research expenditures in the United States will be more than all research expenditures in the 175 years from 1775 to 1950. Staking claim on part of this vast sum of more than 16 billion dollars will be the best investment you can make in the future. And when your management wants to know what to do next you will be in a position not only to answer the question but to do it.

Presented at the Special Conference "Planning New Products," American Management Association, Drake Hotel, Chicago, Ill., Feb. 24–26, 1960.

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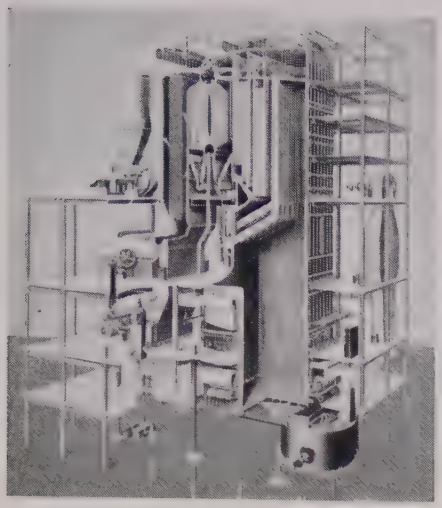

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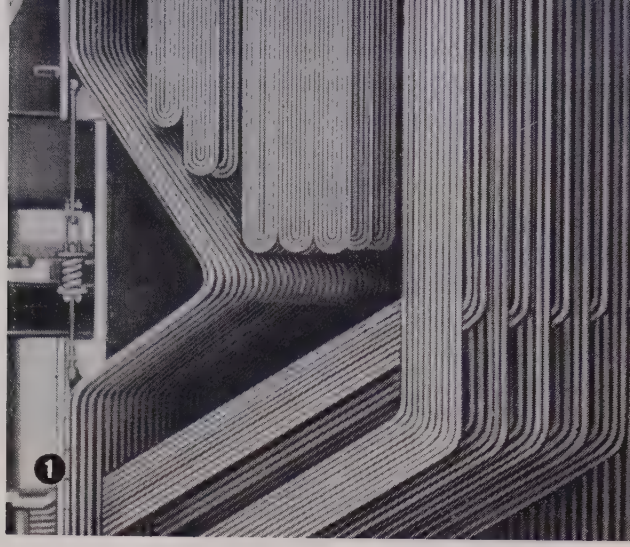

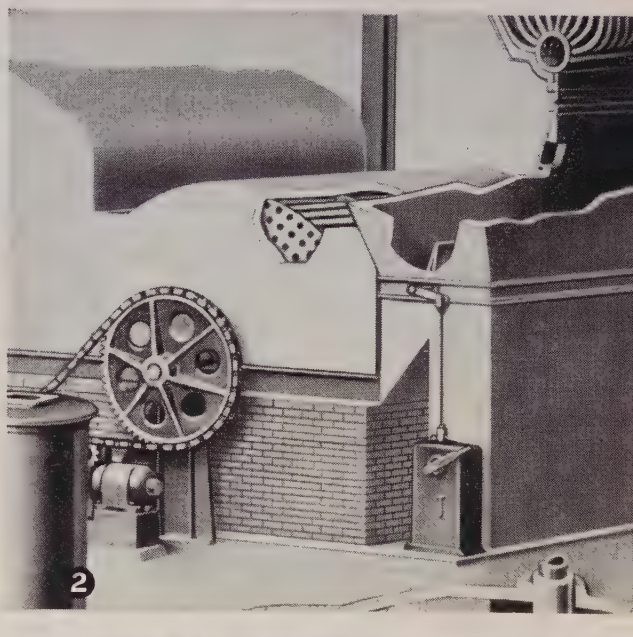

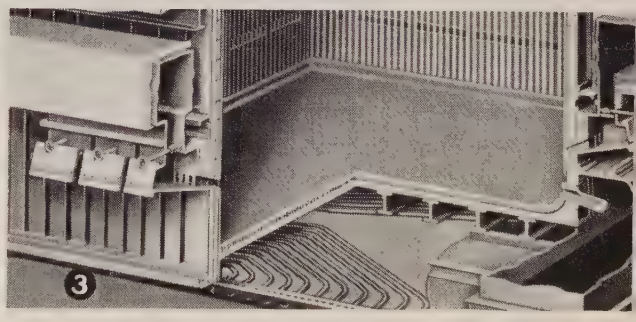

A Look at the Future in the Packaging Industry

C. G. MORSE

General discussion of plastic-paper combinations in the packaging industry and a review of the problems involved with the impact of all-plastic packages in the food packaging industry.

We are entering the era of the "Surging Sixties" and all forms of industrial endeavor in this country are expected to make great progress within the next decade (*14*).

Experts predict that the packaging industry alone will almost double in size in this decade, from an annual gross volume of 16 billion dollars per year to 35 billion dollars per year (*1*).

This extreme growth will be realized as a result of the following factors: (1) increased efforts in marketing research, (2) increased efforts in product development, (3) attraction of top technical personnel into the packaging field, (4) reduction in overall packaging costs, and (5) automation of all packaging lines.

The Sealright-Oswego Falls Corp. pioneered in the packaging industry, utilizing paperboard and manufacturing containers and closures for the packaging industry from this base material. From that humble beginning the company has progressed into an elaborate production setup involving various combinations of paper with plastics in the manufacture of containers for this industry. We plastic coat our products for both the decorative and functional properties.

At the Twelfth Paper-Plastics Conference I was privileged to give a paper concerning plastic coating and the manufacture of paper food containers (*2*), and discussed coating requirements, formulations, and equipment. At that time I discussed the possible impact of an all-plastics package on the packaging industry and what we in the paper-plastics industry must do to meet the challenge in the container field (*3*).

Although the title of my paper would lead you to believe that I will be using crystal ball techniques in predicting what will happen in the future in this industry, this is not the case. This will be more in the nature of a progress report and an updating of my 1957 paper to show you what actually has happened in the 3-year interim period to the nested container and closure industry insofar as paper-plastics and all-plastic containers and closures are concerned.

It is quite obvious that the plastics industry has used point one to very good advantage, and that a very thorough market research has been made. Their figures show them that even a very small share of the paper packaging market represents a ready, lucrative field for their products, if they can meet the cost and quality requirements.

Also, based on the tremendous rapid strides that have been made in the all-plastic container field we would state that the plastics industry has taken advantage of point 5 and that top scientific personnel is now operating in this field. They have also made great advances in their own product development and in many cases have reduced costs to a level at or below that of paper, or a paper-plastics combination (*4, 5, 6*).

C. G. Morse, Sealright-Oswego Falls Corp., Fulton, N. Y.

At the outset it will be necessary for us to establish some definite parameters to limit the scope of this paper, and we will then be discussing the following:

1. *Paper.* We are referring here to plain paper containers converted in the normal manner, utilizing regular paper webs and standard fourdrinier or cylinder boards.
2. *Wax-Coated Paper.* We will be referring here to normal, plain containers made up with standard conversion methods and then dipped in hot wax for protection.
3. *Plastic-Coated Containers.* Plastics are used here to upgrade the paper stocks and we are limited by the base substrate to such mechanical operations as are practical in the conversion of paper. Containers discussed will be precoated, that is, the conventional paper web coated prior to the fabrication of the article. We will not specify the type of coating other than to point out that it will be either vinyl or polyethylene resin. We will also be referring to postcoating of some of these containers where the package is made up and coated after fabrication with an emulsion or latex spray or similar coating method, for protection.
4. *Plastic Containers.* We will be discussing here molded plastic containers made from conventional injection molding methods, or from a vacuum formed sheet plastic raw materials.
5. *Foamed Plastic.* Our references here will be to molded foamed plastic containers made from plastic beads containing an expanding agent which when heated expand and knit together to form a rigid, foamed plastic article of very light weight, due to the incorporation of air cells in the foam.

Therefore, with these parameters in mind we would like to trace for you the development of various nested type, round containers in two separate lines with their attendant closures to show you the present possibilities in the container field. There has been in recent years a tremendous increase in the take-out food business, the automatic food vending industry, and other phases of single-service packaging involving throwaway packages.

HOT DRINK CUPS

First of all, we would like to take the case of the development of the hot drink cup (see Table I) where it is used in vending service and also for carry-out service, including picnic and home use.

Paper Cup

Until the development of plastic coating, all hot drink cups were made from plain raw paper with the attendant objections of "paper taste," staining of coffee or tea into the paper itself which was unsightly, and the softening of the paper so that the cup became rather soggy, depending upon the degree of sizing. These containers could be vended satisfactorily, but in many cases in carry-out service they were too hot to handle and necessitated the application of a handle for comfort. These containers could be effectively printed in multicolor at low cost, but were not satisfactory for the above reasons.

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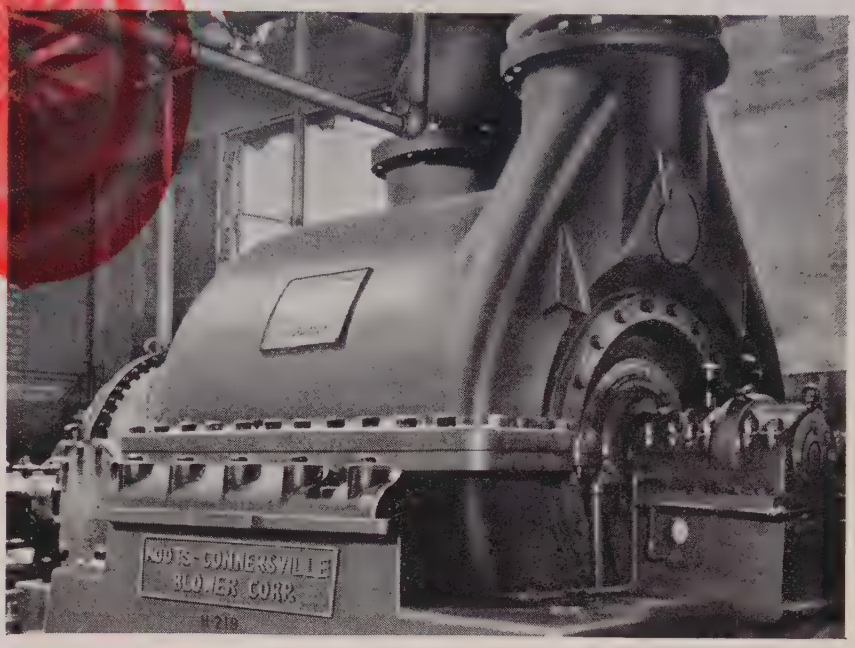
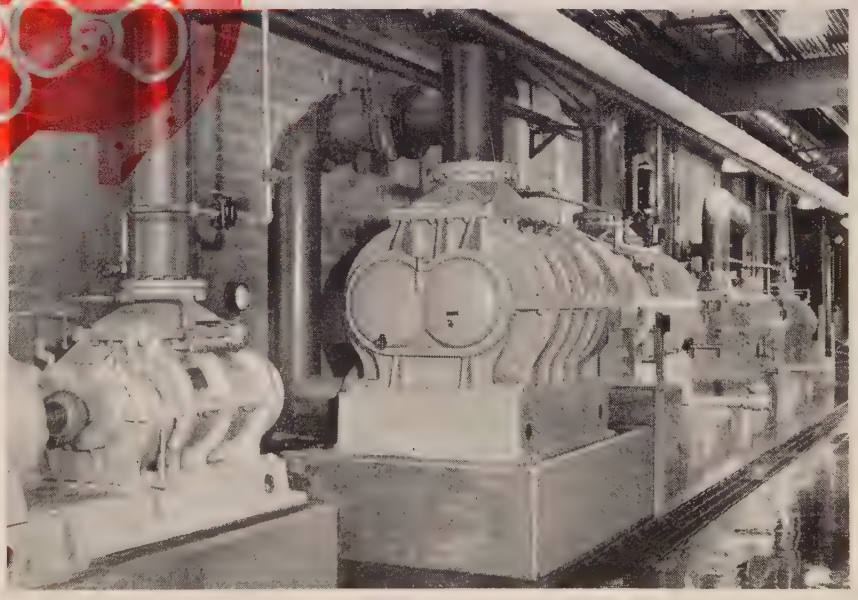


Roots Rotary Pumps supplying vacuum on large paper machine in Texas mill.



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and, later, a hot drink cup. Use of vinyl or polyethylene plastic material upgrades paper to overcome the above objections and to produce an excellent container at only slightly higher cost. With extremely hot carry-out service (212°F.) it is still necessary to use a handle which must be glued on the container for handling comfort. Again, this package can be attractively printed in many colors at fairly low cost.

All-Plastic Cup

The plastic industry invaded this business by producing an injection molded container for this application. It overcame the objections of the plain paper package and was direct competition for the plastic coated paper cup. It did, however, have some other objectionable characteristics. Because of plastic deformation at temperatures in excess of 160°F., it was not satisfactory for use in the carry-out coffee service.

In order to compete costwise it was necessary to reduce the caliper of the plastic to a point where it would not withstand this high temperature. Further problems were encountered with the brittleness of the material and some breakage and distortion occurred so that automatic vending machines were made inoperable. It was also rather impractical to print on this plastic container because of the higher cost and only the use of an expensive label was satisfactory. To further reduce cost and compete with the paper plastic container, the industry perfected equipment for the manufacture of the so-called vacuum formed container which had the same objections as above in many cases. Recent improvements in resin formulation have overcome some of the above objections.

Plastic-Coated Paper Cup

To overcome the objections to the paper taste, softness, and staining of the plain paper container the Sealright Co. developed a coated paper hot drink container

Foamed Plastic Cup

The foamed plastic cup represents an extreme departure from the plastic cup illustrated above in that many of the objections to the all-plastic container are over-

Table I. Hot Drink Cup (Nested)

	Paper	*Plastic-coated paper*	*Plastic*	*Foamed plastic*
1. General	1. Taste	No taste	No taste	No taste
	2. Stains	No stain	No stain	No stain
	3. Softens	No softening	No softening	No softening
2. End use				
A. Carry-out service temp. to 212°F.	Softens badly	O.K. Good	Deforms (sags)	O.K. Good
B. Vending machines temp. to 160°F.	O.K.	O.K.	O.K.	O.K.
Comfort to hand touch (212°F.)	Too hot—need handle	Too hot—need handle	Too hot—deforms	Excellent—no handle needed
D. Comfort to hand touch (160°F.)	O.K. with handle	O.K. with handle	Too hot	Excellent—no handle needed
E. Automatic vending machines	O.K.	O.K.	Some problems due to brittleness and breakage	Some problems due to breakage. Due to wall thickness and taper can't vend easily
3. Decoration—Printing	O.K.—can be attractively printed in multicolors at low cost	O.K.—can be attractively printed in multicolors at low cost	O.K.—printing is more costly. Label can be used—also costly	O.K.—can be printed but some problems due to brittleness of construction
4. Relative raw materials—cost per unit/weight (highest to lowest 1–4)	1	2	3	4
5. Handling and Shipping				
A. Problems	None	None	Some—due to brittleness	Some—due to brittleness
B. Costs (highest to lowest 1–4)	1	2	3	4
6. Closure	O.K.—positive	O.K.—positive	Fair to poor	Poor

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Table II. Ice Cream Container (Nested)

	Paper	*Plastic-coated paper*	*Plastic*
1. General	1. Softens	Firm	Firm
	2. Ice cream shrinkage due to weight loss	Excellent	Excellent
	3. Stains	O.K.	O.K.
	4. Some fiber transfer to contents	None	None
	5. Poor release from containers	O.K.	O.K.
2. End use	Poor	Good	Good
3. Decorative printing	Easily done at low cost—attractively in 3 colors	Same as (1)	Can be printed but some problems—can use label—both more costly
4. Relative raw materials costs per unit weight (highest to lowest)	1	2	3
5. Handling and shipping			
A. Problems	None	None	Some due to brittleness
B. Costs (highest to lowest)	1	2	3
6. Closures	O.K.—positive	O.K.—positive	O.K.—positive
7. Miscellaneous	Not transparent—use window cover or clear plastic	Same as (1)	Transparency of package big advantage

come. As the granules of resin are inflated and fused to produce a rather thick construction of cells of plastic and air entrapped between them, they serve the purpose of providing a material which has not only excellent insulation value, but extremely low cost due to the light weight. This cup does not deform at temperatures up to 212°F. and does not require a handle. The cup can be printed, but there are some problems due to the rather brittle construction. Because of wall thickness, only about one half as many of these cups can be stored in the normal vending machine due to taper problems and this has been an objection. Another serious objection has been the flammability of this cup in that it will burn rapidly and easily, and for this reason has been rejected in some cases by the airlines, although a nonflammable product is being worked on now. One serious problem has been that it is too good an insulation and the user sometimes burns his lips because he does not sense through his fingers that the cup contains an extremely hot liquid. Because of the light weight, the cup tips over easily.

Miscellaneous

Further possibilities along these same lines of development are in the strictly research stage (*9*, *10*, *11*). These involve the possible utilization of foamed plastic materials by direct lamination to paper to form a substrate which can be used for manufacture of paper cups. There have also been some studies made of the use of foamed plastic in combination with sheet plastic materials by lamination to form a substrate for this same application. The further application of improved production techniques to produce this type container involves many new developments to increase the efficiency over the plastic vacuum forming techniques by using blow molding.

NESTED ICE CREAM CONTAINERS (TABLE II)

Paper Container

The Sealright Nestyle container represents a distinctive package used in the sale of ice cream and first containers with this line of packages were plain paper. Experience indicated that the paper package, although usable and low cost, softened and there was considerable shrinkage of ice cream due to moisture loss. In addition, some flavors stained the package badly and there was some fiber transfer when the package was scraped with a spoon to remove the contents. Basically, release of the ice cream from this container was poor. This package could be attractively printed in multicolors at fairly low cost and represented a very attractive, distinctive container, aside from the above problems.

Plastic-Coated Paper Container

Plastic coating upgraded paper stock to overcome the difficulties pointed out above with a plain paper package. The use of the plastic upgraded the paper to the extent that longer term storage could be utilized in packaging ice cream. In order to meet one of the great advantages of a clear, all-plastic package a window-type cover was developed for the plastic coated container so that the ice cream contents could be viewed by the prospective purchaser. This is particularly important in the purchase of marbleized-type ice creams.

Plastic Container

The all-plastic injection molded ice cream container was the first competitive package in this market. The clear container has the decided advantage of transparency and the contents can be seen by the consumer. A further selling point was the reusability of the container for a refrigerator dish or the lid as a coaster. Although transparency of the package is an advantage, there is also a disadvantage in the problems involved in printing directly upon this container. Good progress is being made along these lines but there are still many problems to be solved. One alternative, of course, is to use a pressure sensitive label, but this is quite expensive. Because of the thin wall of this container, there have been problems with breakage not only on the filling equipment, but also in plant handling and by the housewife.

Miscellaneous

We have not included in this survey any of the foamed plastic containers which are satisfactory in the hot drink cup line above, for the simple reason that because of the excellent insulation value of the foam, it is not possible to freeze the ice cream rapidly enough in such a package. However, as we did point out above, there is every possibility that a reduction in the amount of foamed plastic used, and combinations with plastic sheet or with paper itself, can possibly be worked out

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Table III. Cottage Cheese Container (Nested)

	Wax-coated paper	*Plastic-coated paper*	*Plastic*
1. General	Standard of industry	Not satisfactory—leathery but not stiff	Excellent package
2. End use	Possible wax flake problem Softens on long storage	Not acceptable. Too flexible	Excellent
3. Decorative printing	Attractive multicolor. Low cost	Same as (1)	Done at higher cost or use label Plastic can be colored
4. Relative raw material costs per unit weight (highest to lowest)	1	2	3
5. Handling and Shipping			
A. Problems	None	None	Some due to brittleness
B. Cost (highest to lowest)	1	2	3
6. Closures	O.K.	O.K.	O.K.
7. Miscellaneous	Not transparent—use window cover or clear plastic lid	Same as (1)	Resin can be clear or beautiful solid color

with intermediate insulation values to take advantage of the low cost and light weight of the foam.

NESTED COTTAGE CHEESE CONTAINERS (TABLE III)

Wax-Coated Paper Container

For many years this has been the standard of the industry and a wax-coated package has been an acceptable container for cottage cheese. The saturation of paper with wax provides a stiff package wall with fairly good end use. Although the package is passable, there are problems with wax flaking and softening on long storage. The package is not transparent, but a window cover or clear plastic disk or lid have been used to advantage. The sidewall, of course, can be attractively printed in many colors at low cost.

Plastic-Coated Container

Such a package has never been satisfactory, nor developed for this line. We merely bring it to your attention because, although the end use, that is, resistance to cottage cheese, saturation, and so forth is excellent, the package has not met with approval because of the fact that it is not stiff, but leathery. In all other respects it is an acceptable container for cottage cheese.

All-Plastic Container

The transparency of the all-plastic cottage cheese container is an added advantage here, as well as with ice cream packaging. The first offerings made by the plastics industry were in the clear plastic, injection molded, container, but many opaque plastic injection molded containers are also being sold. These are being replaced in many instances by a very excellent vacuum formed package which is not clear. Even though there is difficulty in printing the sidewalls of some of these vacuum formed packages, the development of this unit has neatly overcome this objection by doing all printing on the lid or cover and offering only a color coded sidewall in various attractive pastel colors.

Miscellaneous

As yet, none of the molded foam plastic containers have found their way into this market, but we, here again, anticipate that molded, foamed containers would find some use in this market and be acceptable. Furthermore, combinations of a plastic sheet and foam, or a foam plastic material in combination with paper, certainly would have advantages in this type of container. Another field of potential development along these same lines would be in that of the blow molded package.

CLOSURES (TABLE IV)

All of the above groups of containers require a good positive closure, if we are to have an acceptable finished package for our products. The following groups of closures can be used with all of the types of containers discussed above, depending upon the need in the finished product.

Paper Closure

The plain paper closure was the lowest cost of the original closures for these packages, but gave problems with taste, staining, softening with hot liquids, and of course they were satisfactory with most cold materials.

Wax Coated Closure

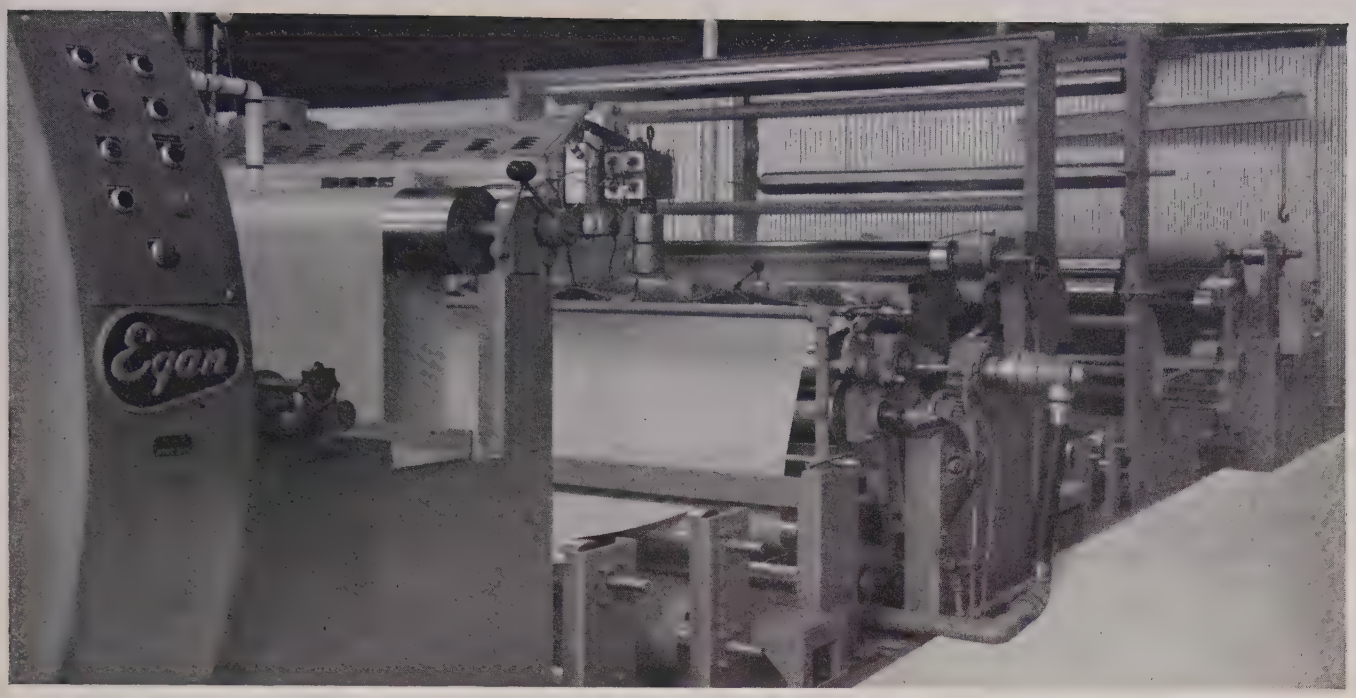
This closure was satisfactory in most instances, particularly with cold items, such as cottage cheese. However, it would melt at high temperature uses and had a tendency to flake.

Plastic Coated Paper Closure

This closure overcomes the objections of the plain

Table IV. Closures

	Paper	*Wax-coated paper*	*Plastic-coated paper*	*Metal*	*Plastic*
1. General—end use	1. Taste	O.K.	O.K.	O.K.	O.K.
	2. Stain	O.K.	O.K.	O.K.	O.K.
	3. Softens—hot liquid	Poor—melts (also flakes off)	O.K.	O.K.	O.K.
	4. O.K.—cold product	O.K.	O.K.	O.K.	O.K.
2. Printing	O.K.	O.K.	O.K.	O.K.	O.K. (a little more difficulty)
3. Relative raw materials cost (highest to lowest)	2	3	4	1	5
4. Handling and shipping					
A. Problems	None	None	None	None	Some due to breakage
B. Costs (highest to lowest) on weight	2	3	4	1	5



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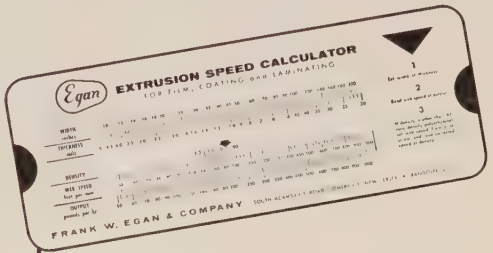

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paper and the wax coated paper closures and is about intermediate in cost. It has found only limited use, however, because of the obvious advantages of some of these other closures.

Metal Closure

Attractive metal closures have found much use in this market and are most satisfactory, the biggest problem being the higher cost.

All-Plastic Closure

This closure is made in clear plastic, or even opaque or colored plastic, both attractively printed. There have been some difficulties in achieving a good printing at low cost and high speed, but these are being overcome.

Miscellaneous

There are yet untouched fields of development in this line, as pointed out previously, representing combinations of foamed plastic with paper and foamed plastic sheet materials to produce closures.

CONCLUSIONS

In conclusion, we must say that paper can no longer be considered as a low cost substrate or a low cost material of construction for containers or closures. We have seen that paper, even in combination with lower cost plastic materials, is losing ground rapidly to the all-plastic containers and closures, due not only to the aggressive scientific approach of the plastics industry to the solution of these problems, but also due to the reduction in cost of resins. In addition, the aggressive technology of the resin manufacturers is producing many tailor-made resins to fit various process changes and developments in vacuum forming and blow molding.

In the past three years we have seen the plastics industry solve their many problems by careful technological approaches. The injection molded articles have been reduced in cost through more efficient molds, and thinner walled containers, that have resulted in savings. Production speeds have been increased, along with improved automation methods. Great improvements have been made in lower cost articles using extrusion and sheet forming methods, at again much lower cost. Vacuum forming of containers seems to have just begun in this field and further developments along the lines of blow molded containers appear to have great potential in this packaging industry to produce a superior and lower cost package. There also appears to be a very great potential in foamed plastics by themselves, or foamed plastics in combination with paper or other plastics, to produce low cost attractive packages.

This is rather a shocking paper to be presenting at a paper industry meeting, but of course I am protected somewhat because this is a paper-plastics conference. We must face the fact that the cost of paper keeps increasing, while the cost of plastics material keeps going down. The use of foam techniques to reduce the consumption of plastic materials and to reduce overall weight is also a real threat. In the past three years we have seen a constant improvement in the quality, number of grades, and types of synthetic materials available to the plastic manufacturer and his technology is constantly improving. On the other hand, paper-making remains in the art category. Paper mills can improve the base stock through the use of beater additives, on-machine coatings, and other applications of technology and technique to reduce overall costs and to tailor-make paper to compete with plastics.

For the past three years we in the paper-plastics industry have stood by and watched the all-plastics industry "take the play away from us." The pulp and paper industry is big business, it is rated seventh in all major manufacturing groups (*12*). We in the paper industry tend to discount the fact of the inroads of plastics because we continue to measure our output in tons as against pounds in the plastics industry. Actually, it is not too late to begin development on competitive paper-plastics combinations, but I am sure that the all-plastic container industry is here to stay and we will have to salvage what part of the overall business that we can.

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Presented at the 15th Paper-Plastics Conference of the Technical Association of the Pulp and Paper Industry, held in Syracuse, N. Y., Oct. 15–17, 1960.

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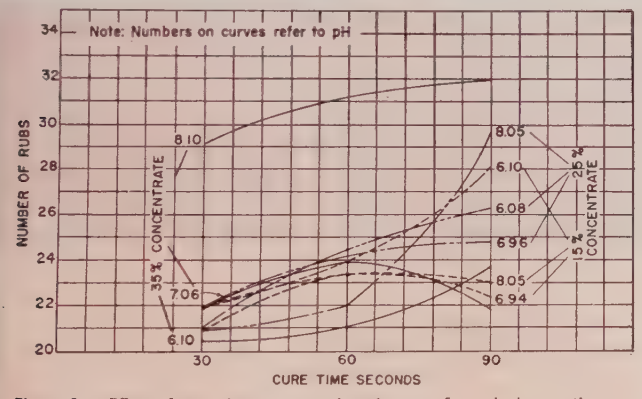


Figure 1 — Effect of cure time on wet rub resistance of starch-clay coatings formulated with Flokote starch plus varying amounts of U.F. Concentrate-85 and applied at different pH levels.

Variables measured were: pH, curing time, urea formaldehyde concentration and type of starch used.

Starches used were National Starch and Chemical Corporation's Nadex 350, a corn dextrin; Flokote, an oxidized starch; and Amioca. Adhesive concentration in all cases was 16-18%, based on weight of dry clay.

WET RUB RESISTANCE

Wet rub resistance, determined on American Instrument Co.'s wet rub tester, increases with cure time. How great an increase depends on the starch, the more reactive starch showing the more pronounced effect. Figure 1, on which pH and amount of U.F. Concentrate used in the trials are parameters, shows this relationship for Flokote.

In all cases, a 25% concentration of U.F. Concentrate-85 (by weight, based on weight of dry starch) gives better results than a 15% addition. However, more than 25% is not generally needed for satisfactory wet rub resistance.

The effect of pH varies, but made no critical difference within the pH range investigated.

PRINTABILITY

Printability, determined by IGT printability tests run on calendered sheets, increases with cure time for a starch such as Flokote (Figure 2). Figure 2 also shows that for Flokote, concentrations of U.F. Concentrate-85 above 25% decrease printability, and that printability decreases with increasing pH.

With the more reactive Amioca starch, neither cure time nor pH has much effect on printability. However, printability increases with the amount of concentrate added.

ACTION OF U. F. CONCENTRATE

Experimental results show that U.F. Concentrate-85 is composed of methylolureas in equilibrium with free formaldehyde. All the contained formaldehyde is available for further reaction — in this case, to form stable, resinous products involving chemical linkages of the starch and cellulose. These are the same reactions for which coaters use formaldehyde and its methylol derivatives.

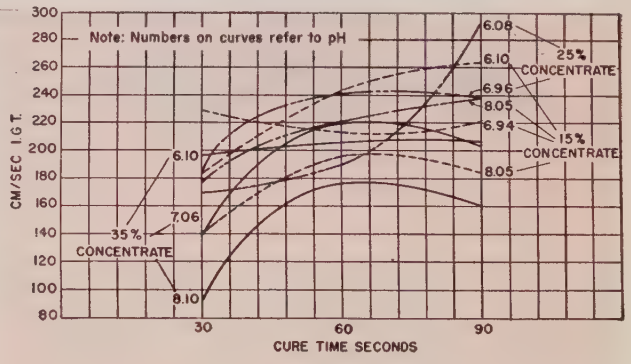


Figure 2 — Effect of cure time on printability of paper coated with starch-clay colors containing Flokote starch plus varying amounts of U.F. Concentrate-85 and applied at different pH levels.

U.F. Concentrate-85 contains 85% active ingredients — 60% formaldehyde and 25% urea, by weight. You'll find complete information on it in Allied Chemical's 36-page brochure, "U.F. Concentrate-85". Also available is a reprint of an article describing details of its use to improve starch-clay coatings. Write for your copies today. 2819

BASIC TO AMERICA'S PROGRESS

Allied Chemical

NITROGEN DIVISION

Dept. UF 7-28-5, 40 Rector Street, New York 6, New York

PRODUCTS and SERVICE...

OK BRAND Pregelatinized—ready to use—beater starch.

OK BRAND Cationic—effective—economical wet end additive.

OK BRAND Enzyme converting starches for sizing and coating adhesives.

OK BRAND Oxidized starches—complete line for sizing and coating adhesive application.

OK BRAND A new line of corn starch derivatives for sizing and coating adhesive application.

OK BRAND Economical—controlled viscosity thinboiling starches for special sizing applications.

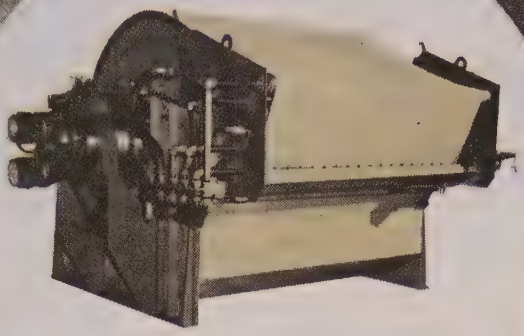
to meet your changing needs

Mistakes are costly. That's why you'll want to rely on Hubinger products and field service. For over three-quarters of a century, we've been developing, testing, and manufacturing starches and adhesives—always looking for new and better products. And, these products are serviced by trained field personnel, men who can help you solve the most complicated starch and adhesive problems. If your mill needs new starch products to meet special specifications, let our nearby Hubinger paper-starch technical service representative help you. You can depend on him—and Hubinger products—to meet your changing needs and do so economically.
Just phone or write us.

THE HUBINGER COMPANY / *Keokuk, Iowa*

New York • Chicago • Los Angeles • Boston • Charlotte • Philadelphia

In Pulp and Paper Mills...



EIMCOBELT® FILTERS

"On Stream" Continuously

From recausticizing service to handling difficult waste streams, EimcoBelt filters have proven capable of staying "on stream" continuously, with no production slowdowns or shutdowns caused by progressive blinding of filter media.

EimcoBelt continuous belt filters have resulted in lower equipment and installation costs when employed for the washing and dewatering of lime mud from the white liquor clarifier underflow. Also, operating savings were realized when EimcoBelt filters were installed in mills to handle deinking wastes and total mill wastes.

These new steps forward in filtration practice are possible because EimcoBelt filters successfully remove the belt filter medium from the drum every revolution for complete cake discharge and medium washing. The medium is scoured clean with high velocity wash sprays on both sides before being returned to the drum. Blinding is eliminated.

Ask the Eimco Representative in your area to help you estimate savings in your operations with EimcoBelt filters. Write Eimco Filter Division, P.O. Box 300, Salt Lake City, Utah, U.S.A. for Bulletin FT-2053.

The EIMCO® corporation
Head Office: Salt Lake City 10, Utah, U.S.A.
Export Office: 52 South St., N.Y.

"Advanced Engineering and Quality Craftsmanship Since 1884"

B-746

HAM FELTZ says:

"Reminds me of HAMILTON Felts' technical advances!"

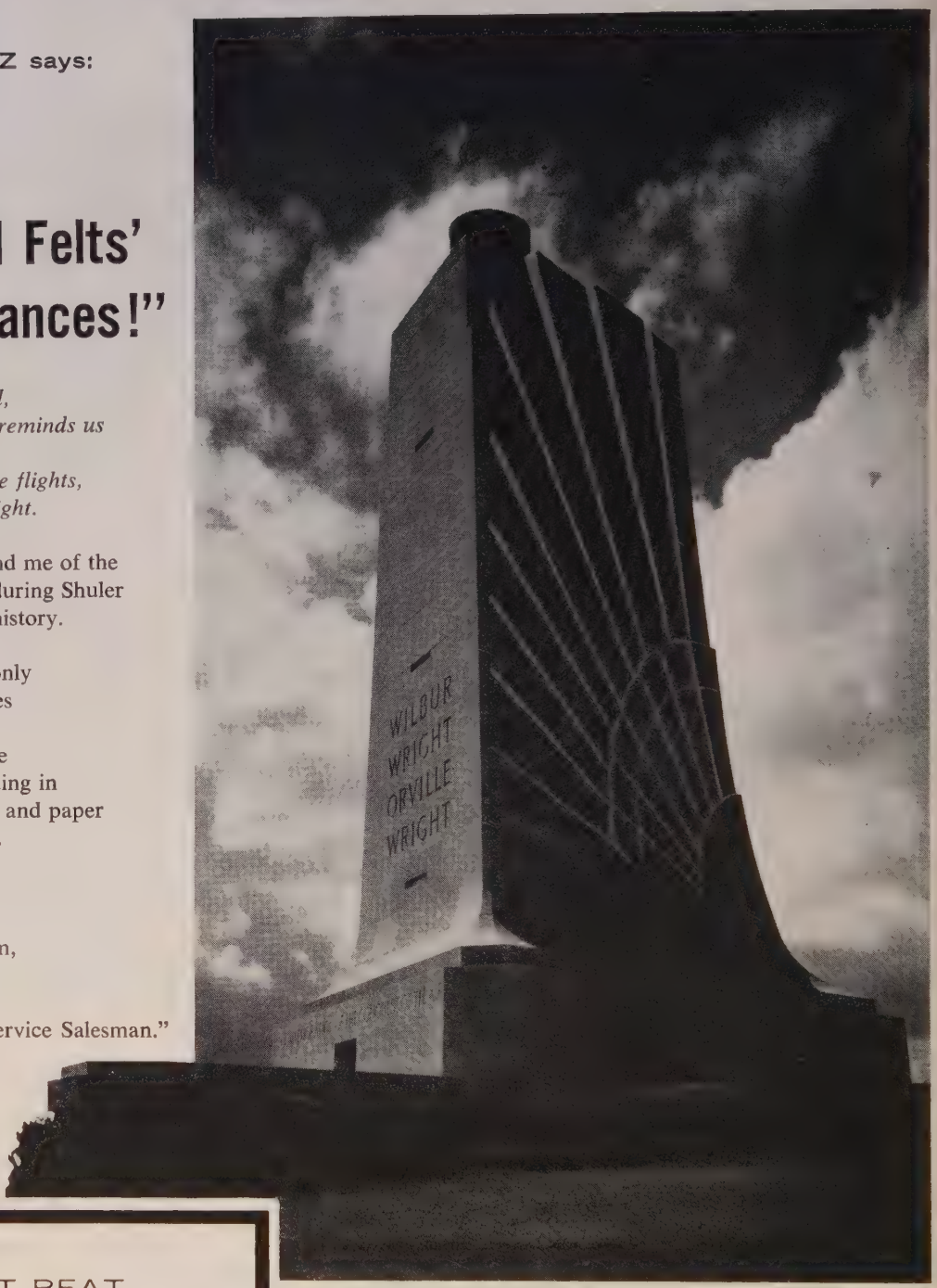
"The Wright Brothers' Memorial, at Kitty Hawk, North Carolina, reminds us of a great technical advance — the first engine-propelled airplane flights, made by Orville and Wilbur Wright.

"Similarly, Hamilton Felts remind me of the many technical advances made during Shuler & Benninghofen's 102-year old history.

"For, Hamilton Felts have not only kept pace with the great advances in papermaking technology, but, in many cases, have helped make these advances possible — resulting in the manufacture of better board and paper at higher speeds and *lower costs.*

"If one of our 300 modern, technically proved patterns won't solve *your* specific problem, we'll be happy to design a Hamilton Felt that will. Just ask your Hamilton Felts Service Salesman."

*Idea submitted by Harold E. Rowland, Continental Can Co. Inc., Hopewell, Va.
Photo by: Ewing Galloway, New York



YOU CAN'T BEAT
Hamilton
FELTS

*WIN . . . A NEW Shakespeare Spincast Fishing Outfit!

"What famous place reminds you of Hamilton Felts? Tell us why in a few words; sign your name and address and name of company . . . Each idea from a U.S. papermaker that we use wins a new 1961 model Shakespeare Spincast Rod and Reel—FREE! When identical winning ideas are submitted by 2 or more papermakers, the one with the earliest postmark will be considered the winner. Every U.S. papermaker *entrant* receives a famous Rex Spoon fishing lure—FREE. Send me your suggestion—today. Ham Feltz, Dept. T, 612 First National Bank Bldg., Cincinnati 2, Ohio."

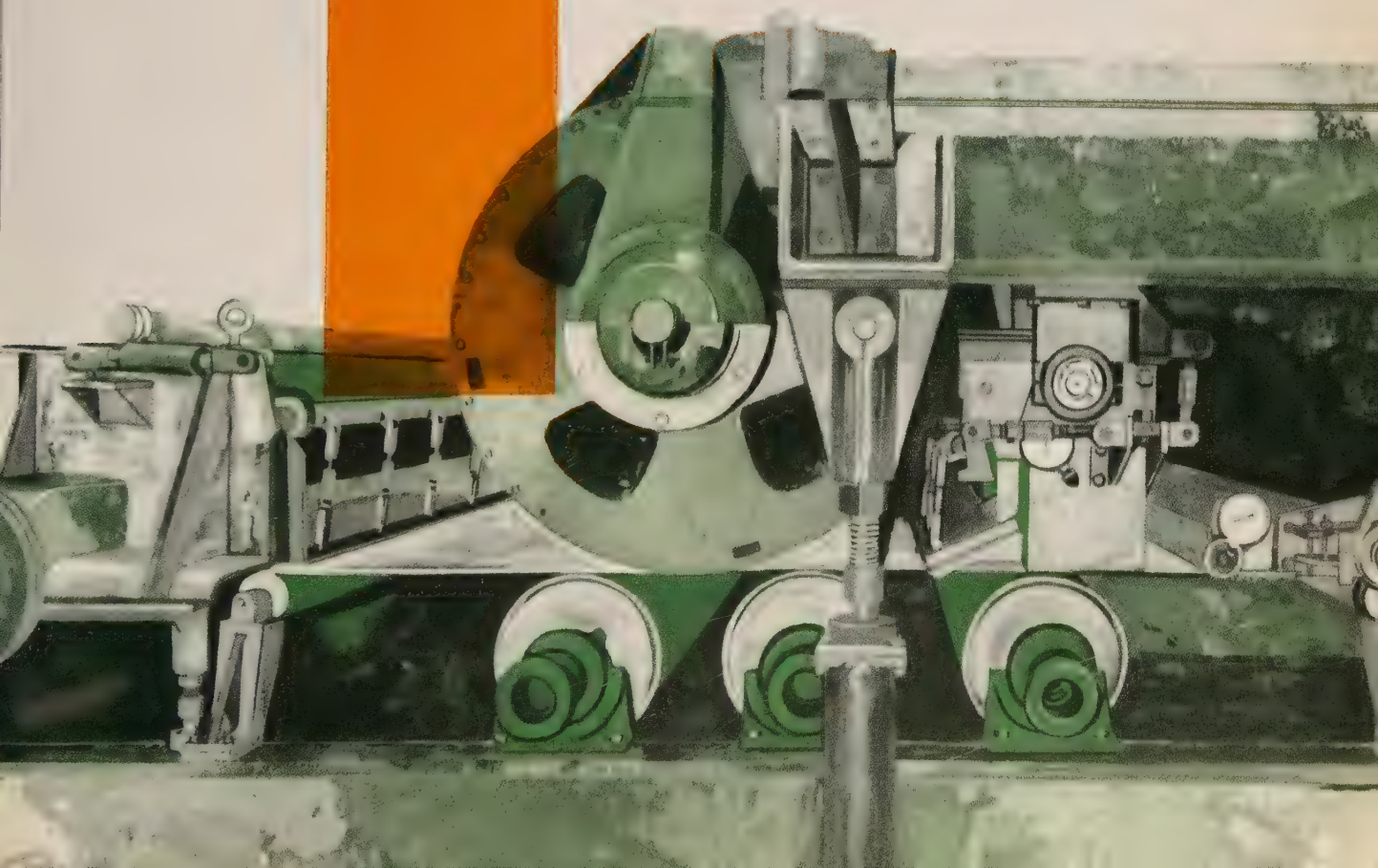
SHULER & BENNINGHOFEN, HAMILTON, OHIO

what dramatic
new developments
does the

INVERFORM

bring to
papermaking?

for answer, please turn page



INVERFORM*

offers new horizons to the paper industry

This new papermaking technique, embodying both Fourdrinier and cylinder machine principles, can be used in both paper and board manufacture. Inverform is a forming device which reorients fibers following their initial delivery to the wire and accomplishes water extraction in the two vertical planes. Inverform introduces the possibility of producing grades with new and improved characteristics at higher speeds than now possible, and offers the potential of new products now unknown to the industry.

- Paper grades that are made by Inverform have good formation and improved strength characteristics.
- Slower draining stocks can be run at higher speeds.
- Boards can be made with improved quality at higher speeds.
- Inverform assures excellent ply adhesion on multi-ply applications.

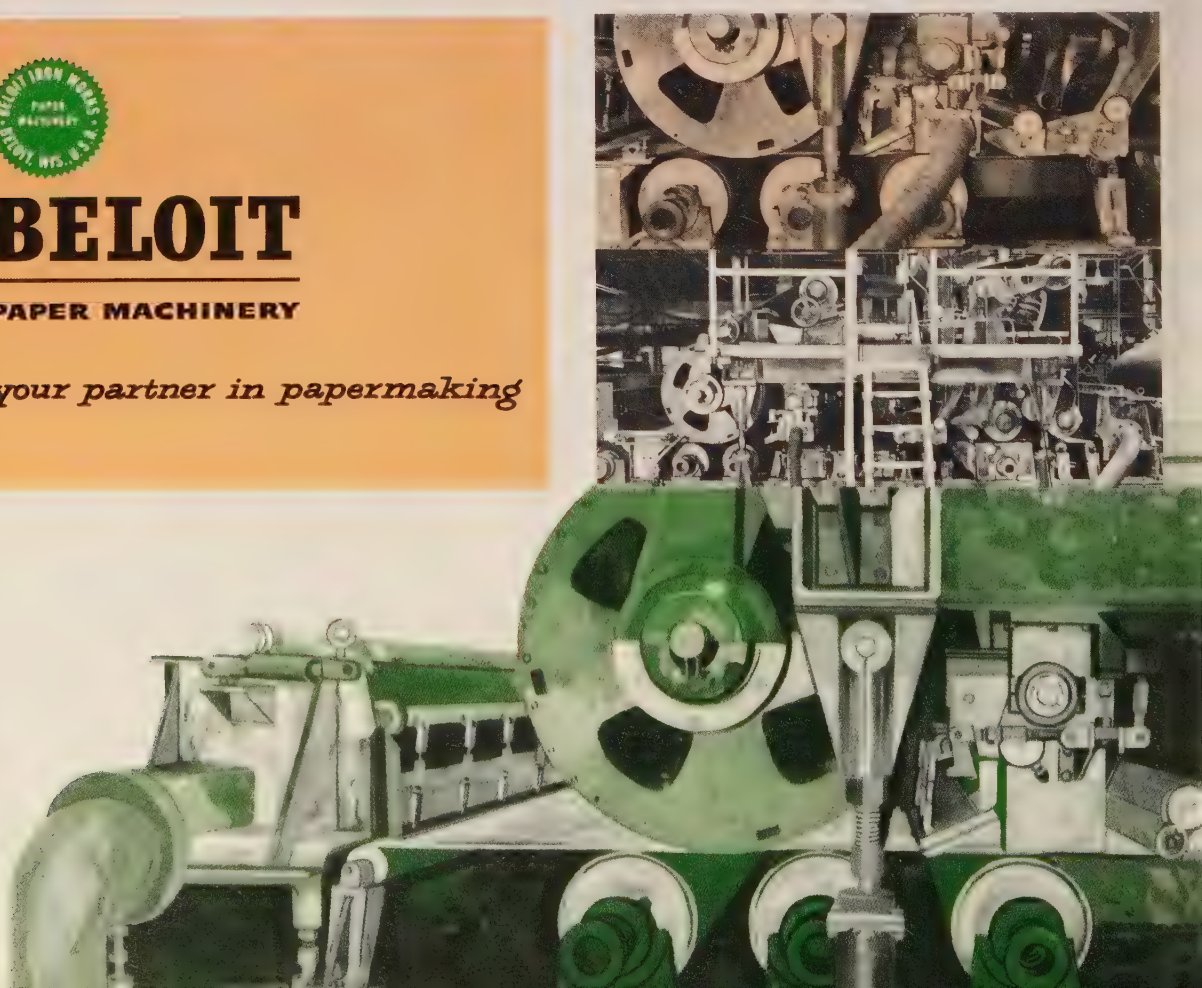
(BELOIT IRON WORKS builds Inverforms under license from ST. ANNE'S BOARD MILL CO. LTD.)

*Patented United States, United Kingdom and others

BELOIT

PAPER MACHINERY

your partner in papermaking



A new Kraft mill at Woodfibre, British Columbia, is on stream! Specifically designed to produce great paper-making pulps, competitively priced, Woodfibre is now turning out FIBRENIER —first of a new family of advanced pulps that offer the papermaker important new opportunities for strength, brightness, formation, opacity and smoothness.

FIBRENIER is an all-new blend of western red cedar (for Mullen, tensile and fold . . . plus opacity and surface smoothness); Douglas fir (for exceptional tear strength); western hemlock (for high freeness and balanced strength properties)—another achievement of Rayonier Research.

See for yourself just how great FIBRENIER is. Call your Rayonier representative collect today. Samples and tonnage quantities are ready. Or write for complete data. No obligation.

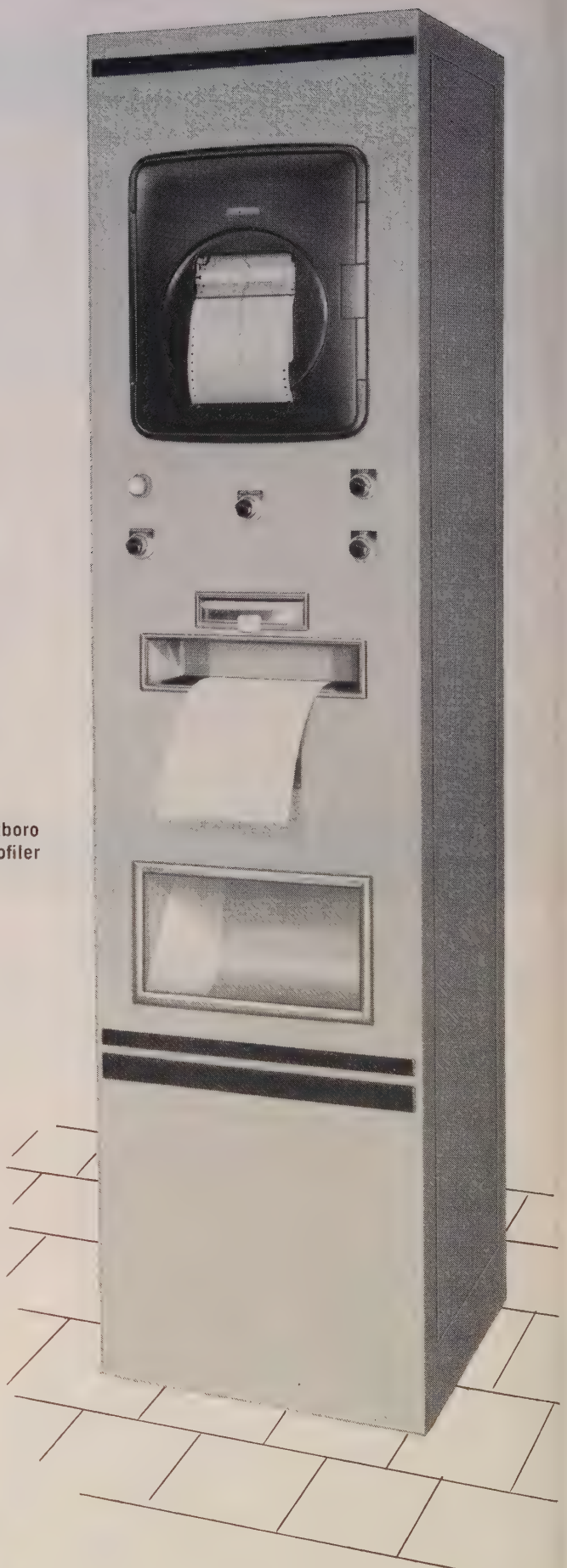
RAYONIER

GREAT PAPER-MAKING PULPS

Rayonier Incorporated
161 East 42nd Street
New York 17, New York

For The World's Leading Papermakers — The Complete Line of Fibers • Bleached sulfates: western softwood, western red cedar, southern pine and southern hardwood. Bleached sulfites: western hemlock, southern pine.

automatic profile record of paper and board thickness



the Foxboro
Caliper Profiler

Put in a sample strip, push a button, and in a matter of minutes Foxboro's Caliper Profiler automatically gives you a continuous chart record of sheet thickness — all the way across the sheet.

The Foxboro Caliper Profiler meets all standards published in TAPPI's Code T411 m-44. It's accurate to 1/10,000 of an inch — takes samples up to 0.120 of an inch thick.

The Profiler offers a new high in quality control. Its continuous profile record shows exactly where caliper is off. No more time-consuming spot checks with hand micrometers. No awkward, cumbersome testing machines.

Get full details on how this remarkable Foxboro instrument can help you control the quality of your paper and paperboard. Write for Bulletin 10-12A today. The Foxboro Company, 786 Neponset Ave., Foxboro, Mass.

FOXBORO

REG. U.S. PAT. OFF.

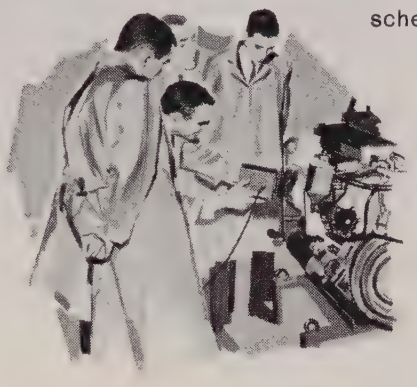
INSTRUMENTATION FOR THE PULP AND PAPER INDUSTRY

This is AMERICAN OIL COMPANY

Our organization has more than 70 years' experience in the oil business. We are one of the largest petroleum organizations in America.

We believe the experienced American Oil representative who calls on you, plus the waxes, the petroleum products and the facilities which he has at his disposal, are reasons why you will like to do business with us.

Your American Oil representative receives special training for his job at our Sales Engineering School. He is given concentrated basic instruction in all phases of petroleum product quality and application—including waxes. According to a planned schedule, he returns for an advanced course and then again for post-graduate work.

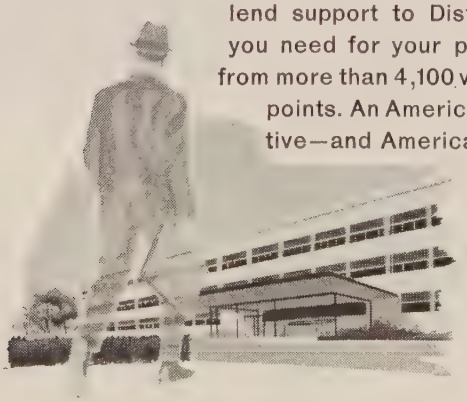


In our Marketing Technical Service Department are specialists who are recognized authorities in their fields. These senior consultants may be called in to work with you on any specialized wax application or lubrication problems.

More than 1,000 research scientists and technicians are at work in our research laboratories developing new products and finding ways to improve present products. Their mission: To help your American Oil representative help you lower your maintenance costs and stretch your maintenance dollars.

Twelve American Oil refineries give flexibility to the production of petroleum products and waxes for industry. They help make it possible to assure prompt delivery.

American Oil representatives operate from 74 District Offices. Thirteen Regional Offices strategically located throughout the country lend support to District Offices. The products you need for your plant or fleet are available from more than 4,100 warehouses and distribution points. An American Oil Company representative—and American Oil products—are only a telephone call away. We invite you to make that phone call. Or write **American Oil Company, 910 South Michigan Avenue, Chicago 80, Illinois.**



AMERICAN OIL COMPANY

Trial runs can be set up in your plant by Dow technical personnel. For full details, just call your nearest Dow sales office.

paper processing chemicals

VERSENEX 80

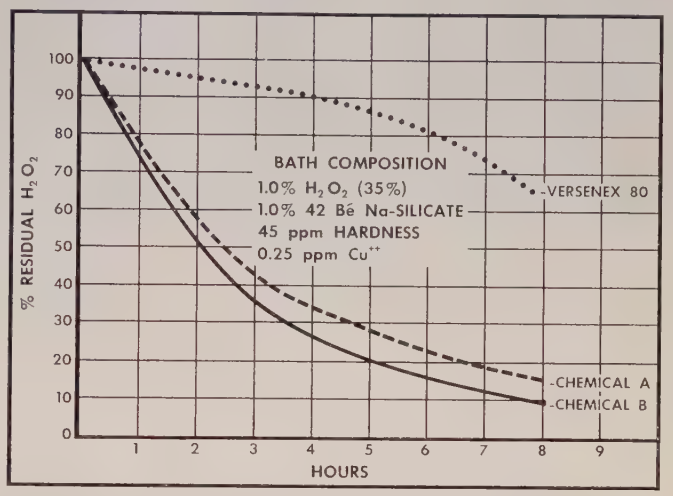
SAVE UP TO $3.50/TON IN GROUNDWOOD BLEACHING, IMPROVE BLEACHING EFFICIENCY WITH VERSENEX 80

Actual mill use is showing substantial savings in bleaching costs by the addition of Versenex® 80 chelating agent to groundwood pulp before bleaching. In some cases, brightness levels are maintained with less peroxide when Versenex 80 is used as a pretreatment. In others, gains in brightness are achieved without increasing peroxide concentration. In either instance, the cost per point of brightness is lowered.

Improvement in the bleaching process with Versenex 80 lies in the fact that peroxide bleach liquors are subject to rapid decomposition. In groundwood bleaching, some 20-30% of the effectiveness of the bleach liquor is "lost," mainly because of the catalytic action of heavy metal ions present in the liquor. Inactivation of these ions by Versenex 80, before the bleach tower, extends the effective life of the peroxide. As a result, savings of up to $3.50 per ton in chemical costs are being realized in actual mill operation.

A comparison of Versenex 80 with other commercially available aminocarboxylic acids is shown in the graph at right. Versenex 80 pentasodium salt of diethylenetriaminepentaacetic acid is shown to be significantly superior to either tetrasodium salt of ethylenediaminetetraacetic acid (chemical A) or trisodium salt of N-hydroxyethylethylenediaminetriacetic acid (chemical B) for this application.

Where stray metal ions are causing reversion, scaling, and other bleaching problems, investigate Versenex 80. For more technical information or for a trial run in your own plant, call your nearest Dow sales office or write us in Midland.



NEWS ON MILL SAFETY

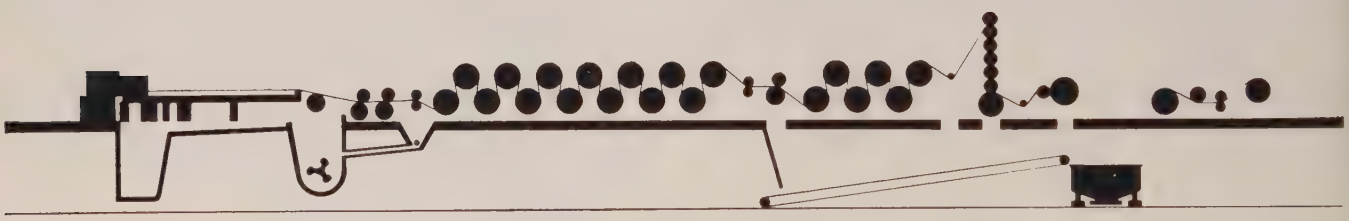
is being made by another Dow product—Chlorothene® NU. It's a cold-degreasing solvent that has no fire or flash point measurable by standard methods and has low toxicity. It may be used by spray, dip, or wipe methods. You can use it safely to clean instruments, oily or greasy parts, calender stack rolls, most electric motors, and in the removal of pitch from the wire. Ask for complete information on this new safety solvent for your maintenance cleaning.

THE DOW CHEMICAL COMPANY DOW Midland, Michigan

IMPCO "BROKE HANDLING" SYSTEM AT FRASER PAPER, LTD.

The Press Section Repulper-Conveyor discharges 30 per cent consistency web to the couch pit.

This is Fraser's Solvo Pulper on its way to the mill. It's our Duplex model with twin pulping elements.



Here's how Fraser handles broke on their new high speed 234 inch paper machine at Madawaska, Maine. They do it with an Impco 36″ Cantilevered Agitator in the couch pit — an Impco Repulper-Conveyor at the press section — and an Impco Solvo Pulper at the dry end. The Solvo installation features: conveyor belt loading — batch or continuous pulping — and built-in pumps for simultaneous pulping and pumping action. When batch pulping, they are obtaining spot-free discharge on even their most difficult grades such as wet strength and 27 to 60 pound hard-sized bond sheets.

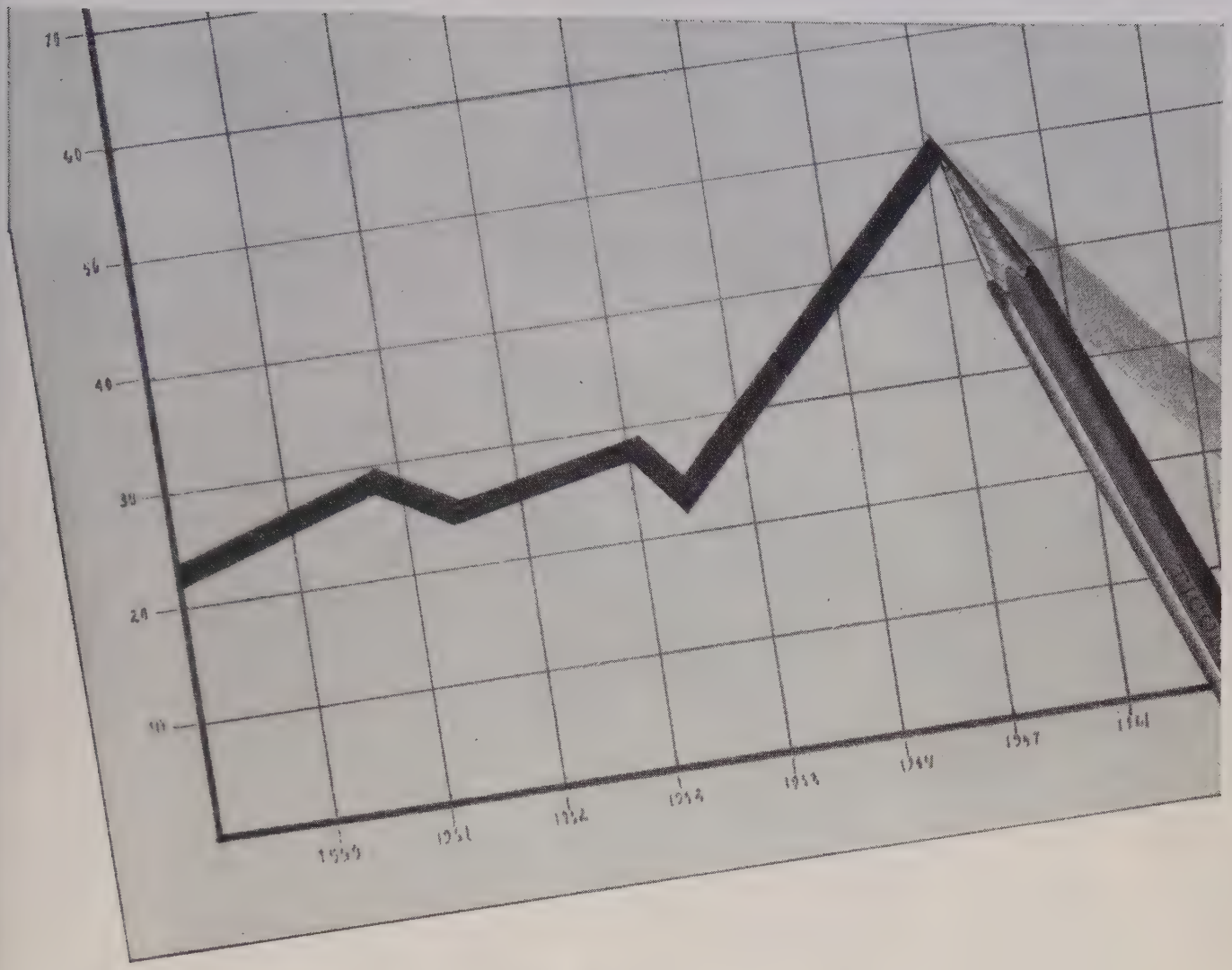
Let us help you solve your broke handling problem from any position on your machine.

IMPCO®

IMPROVED MACHINERY INC.

NASHUA, NEW HAMPSHIRE

IN CANADA: Sherbrooke Machineries Limited, Sherbrooke, Quebec



A good line to remember

Mark this down with your lines of truth: "Coated stock with a uniform finish makes sales go up." CLINTON starches and dextrins make sure your coating is consistently smooth and free from "skips." When gloss printing quality and strength count most, use CLINEO starches. And, to improve all-around printability and control curl, specify CLINCAL starches (they contain their own lubricants). With these starches, you can select from many varieties. Customers and prospects who judge paper on its face value can see and feel the difference when you use CLINTON coating starches.

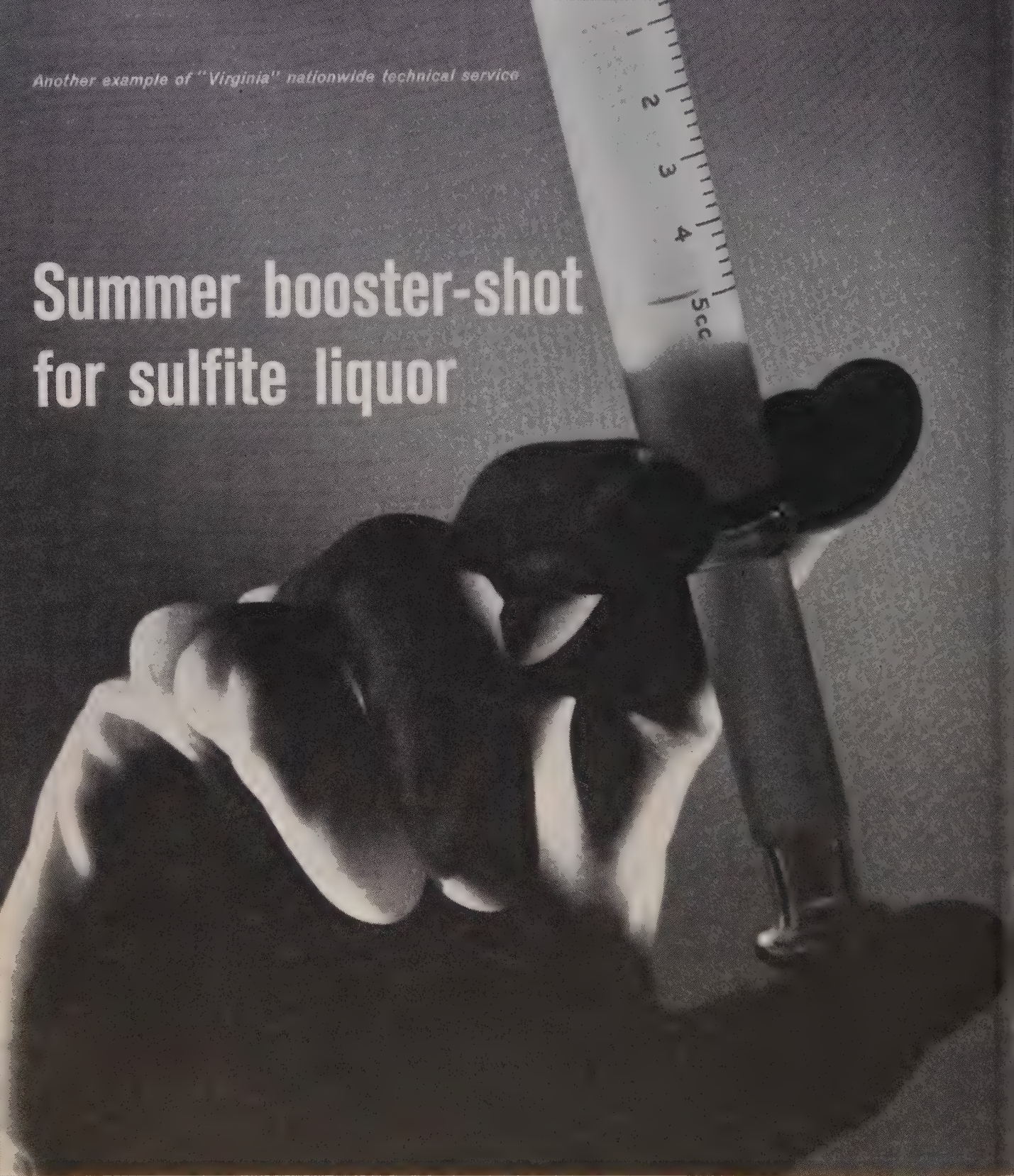
Technical service always available

CLINTON CORN PROCESSING COMPANY

CLINTON, IOWA

Another example of "Virginia" nationwide technical service

Summer booster-shot for sulfite liquor

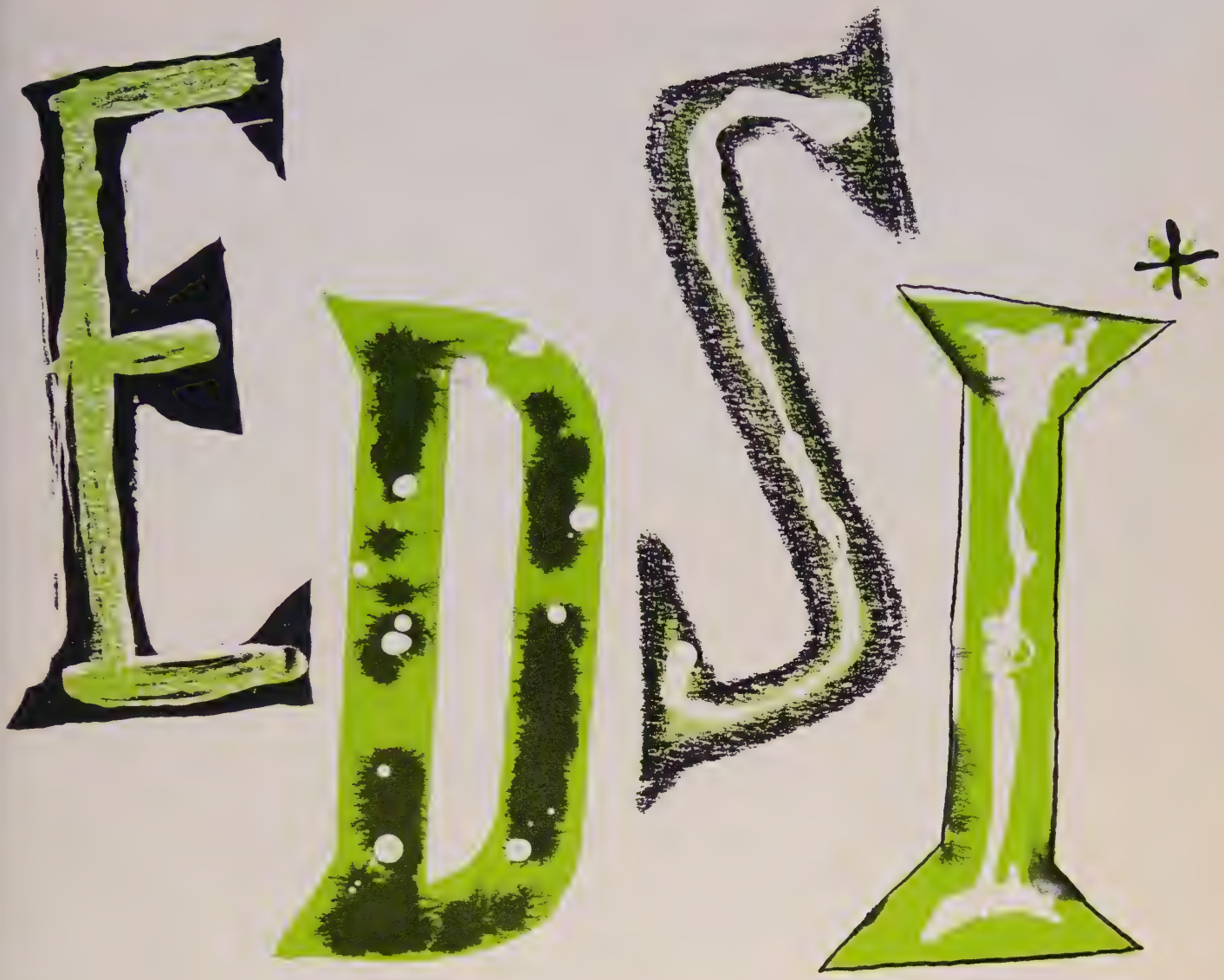


A pulp mill was plagued year after year by an efficiency loss of about 30% in the sulfite acid-making plant caused by summer-warmed water. As a result, both pulping capacity and pulp quality dropped off. The mill people decided to try refortifying their sulfite cooking acid and ordered a tank car of Virginia SO_2 (99.9% pure). We sent a technical service man along. He found best results were obtained by adding liquid SO_2 to the sulfite acid storage tank through an open stainless steel pipe. Strength of the cooking acid was quickly raised to the required 6.5% level. Pleased with the results of this summer-time emergency treatment, the mill took a hard look at year-round variations in acid strength and pulp quality—now plans a permanent installation that will permit efficient use of liquid SO_2 as needed throughout the year. This will assure constant-strength sulfite liquor, a higher yield from the digesters, and a better end product. If your sulfite liquor needs a summer booster shot, write Chemical Division, VIRGINIA CHEMICALS & SMELTING COMPANY, Dept. 319, West Norfolk, Va.

VIRGINIA Chemicals

Field Offices: New York • Boston • Chicago • Atlanta
Asheville • Philadelphia • Akron • Seattle • Memphis

Available in Canada and many other countries



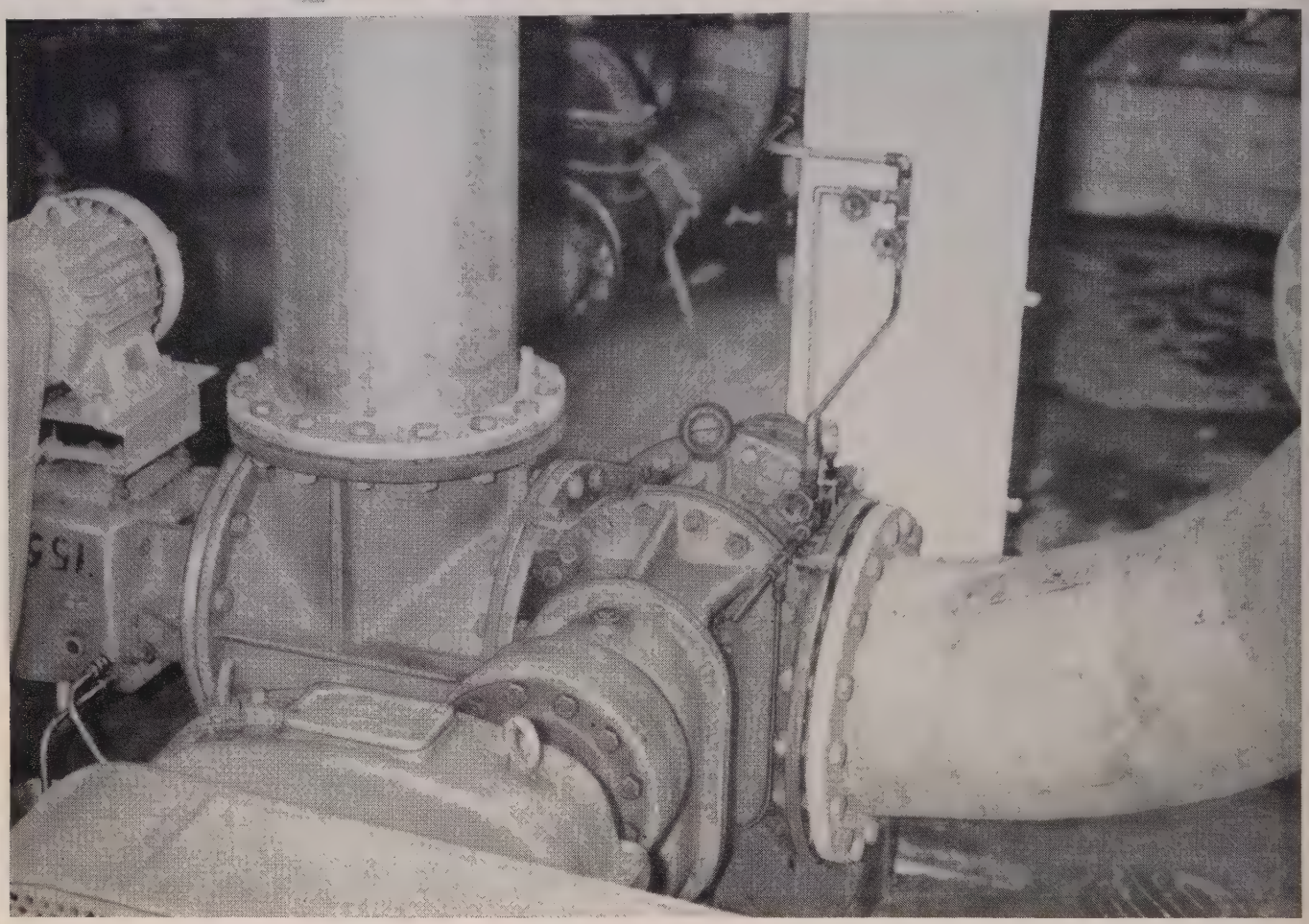
Electronic Draw Speed Indicator

for accurate felt draw and synchronization measurement.

Ask your **HUYCK MAN!**

* Applied exclusively by Huyck Field Service Engineering

Sandy Hill Introduces:



NEW KAMYR High Density PUMP

-- for stock of record high consistencies

The KAMYR High Density Pump moves stock of unusually high consistencies . . . as proved in 135 installations in the United States and throughout the world.

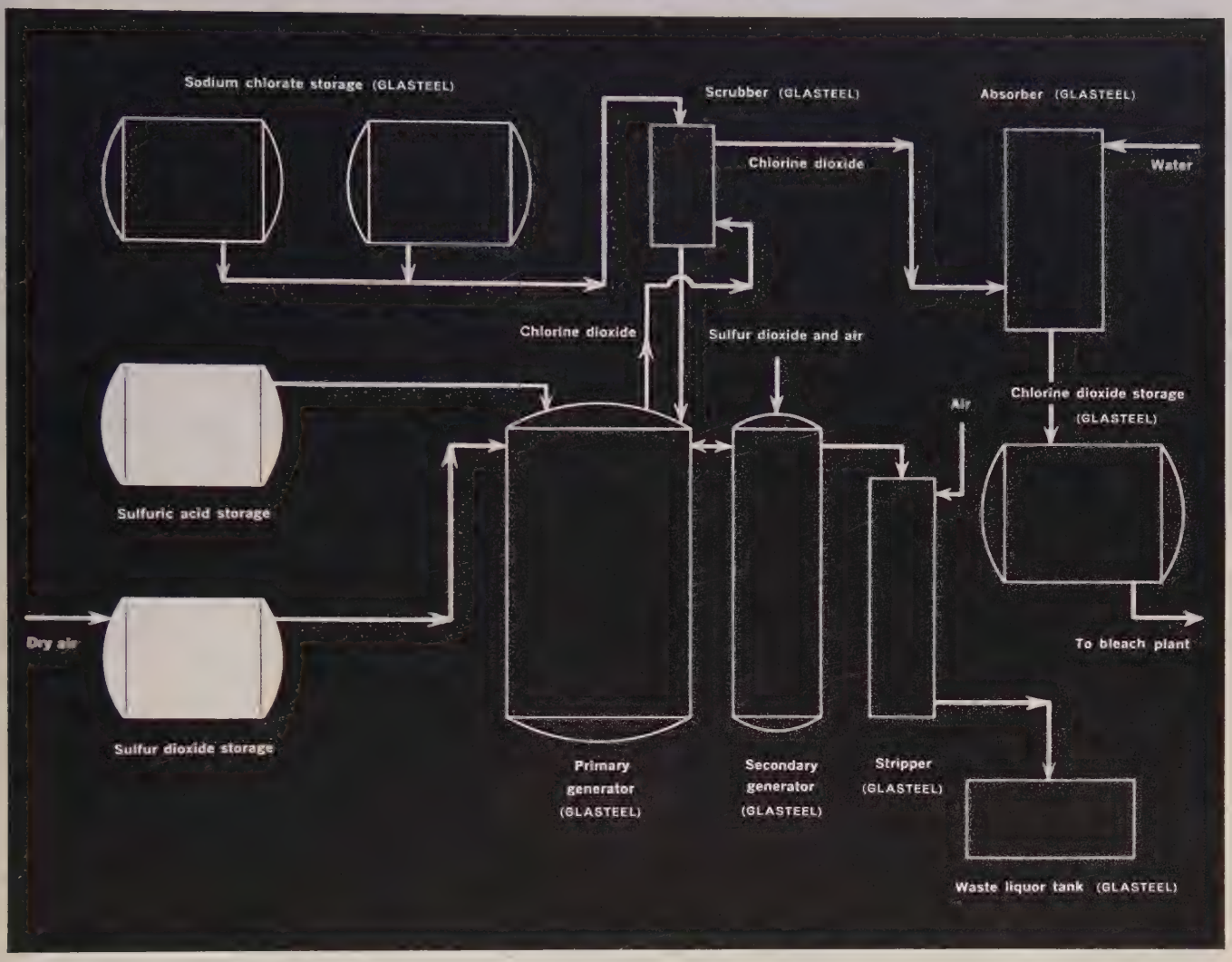
Designed by A. B. Kamyr, Sweden, world leader in pulping equipment, it features low maintenance, easily accessible stuffing boxes, and rotor blades readily replaced without dismantling the pump.

Can be made from a variety of materials, including stainless steel, to meet your requirements.

Call or write Sandy Hill now for complete information

THE
SANDY HILL
IRON AND BRASS WORKS
HUDSON FALLS, N. Y.

FLUIDICS* AT WORK



GLASTEEL ENDS CORROSION in every phase of ClO_2 generation

This flow chart tells the story. Pfaudler® Glasteel has come into its own as the *preferred* material of construction for complete chlorine dioxide generating systems.

With good reason: Glasteel gives you the most useful qualities of both glass and steel. Inside you have glass for *corrosion resistance;* outside, steel for *strength.*

Moreover, with Glasteel there's practically no chance that rust contamination of the chlorate will cause troublesome "puffs."

You'll find Glasteel storage tanks, scrubbers, absorbers, strippers, generators, pumps or piping used in 40 installations throughout North America. In each case the story is the same: Glasteel equipment turns out to be the most economical in terms of cost, maintenance and service life.

In addition to equipment, Pfaudler also offers a complete Project Engineering service — a *temporary* addition to your (or your engineering firm's) staff. We can provide any or all of these functions: (1) Design of system. (2) Selection and specification of equipment. (3) Layout. (4) Procurement and expediting of equipment. (5) Contracting for erection, installation and/or construction. (6) Start-up assistance and personnel training.

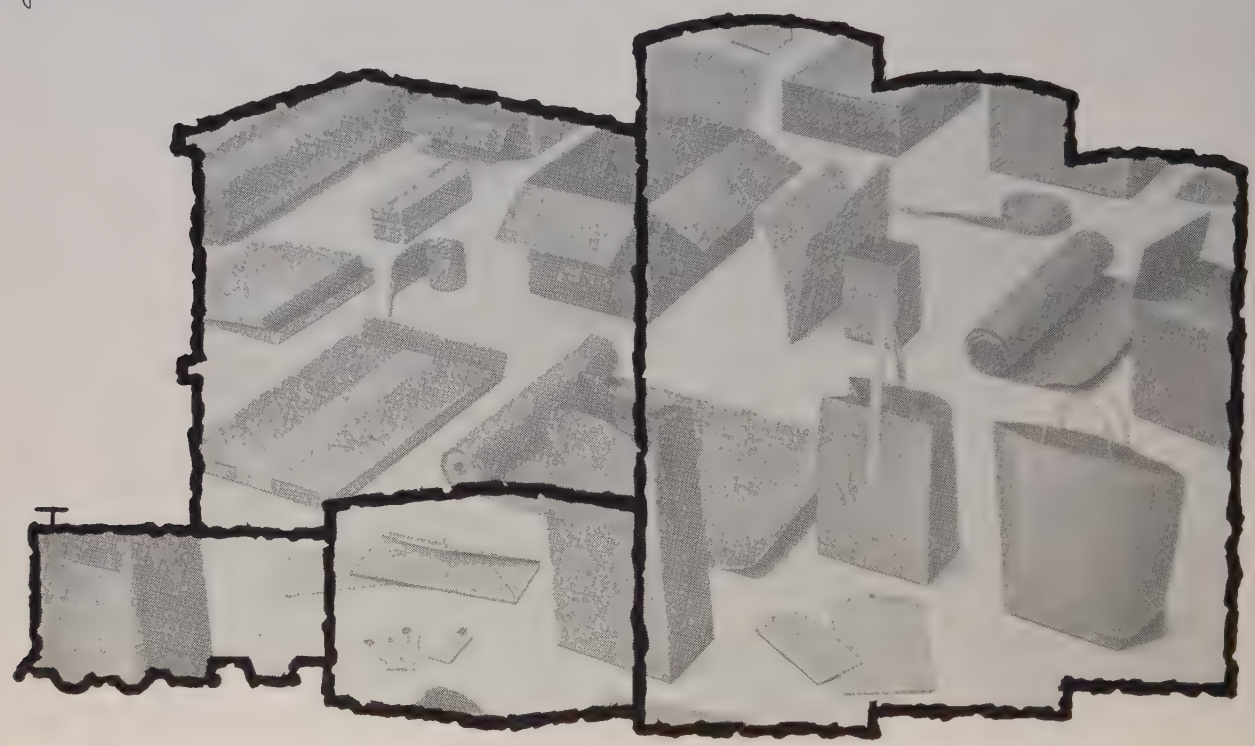
For the complete story of one Pfaudler-engineered and -equipped ClO_2 system, ask for Reprints No. 535 and No. 538. Or direct any questions you have about either equipment or services to our Pfaudler Division, Dept. TA-61, Rochester 3, N. Y.

*FLUIDICS is the Pfaudler Permutit program that integrates knowledge, equipment and experience in solving problems involving fluids.

PFAUDLER PERMUTIT INC.
Specialists in FLUIDICS...the science of fluid processes

WEST END

advance planning OF EXPANDED SALT CAKE PRODUCTION ANTICIPATES INDUSTRY'S GROWING NEEDS



WEST END demonstrates its complete reliability as a major source by the continuing enlargement of its production facilities devoted to the manufacture of highest quality salt cake as a prime product. Independent of other product production and located at the site of vast natural raw material supply, West End is solidly qualified to handle the complete requirements of customers dependably, economically and efficiently.

Stauffer CHEMICALS

WEST END CHEMICAL COMPANY • DIVISION OF STAUFFER CHEMICAL COMPANY

636 CALIFORNIA STREET, SAN FRANCISCO, CALIFORNIA • PLANT: WESTEND, CALIFORNIA

Quality YOU CAN SEE...

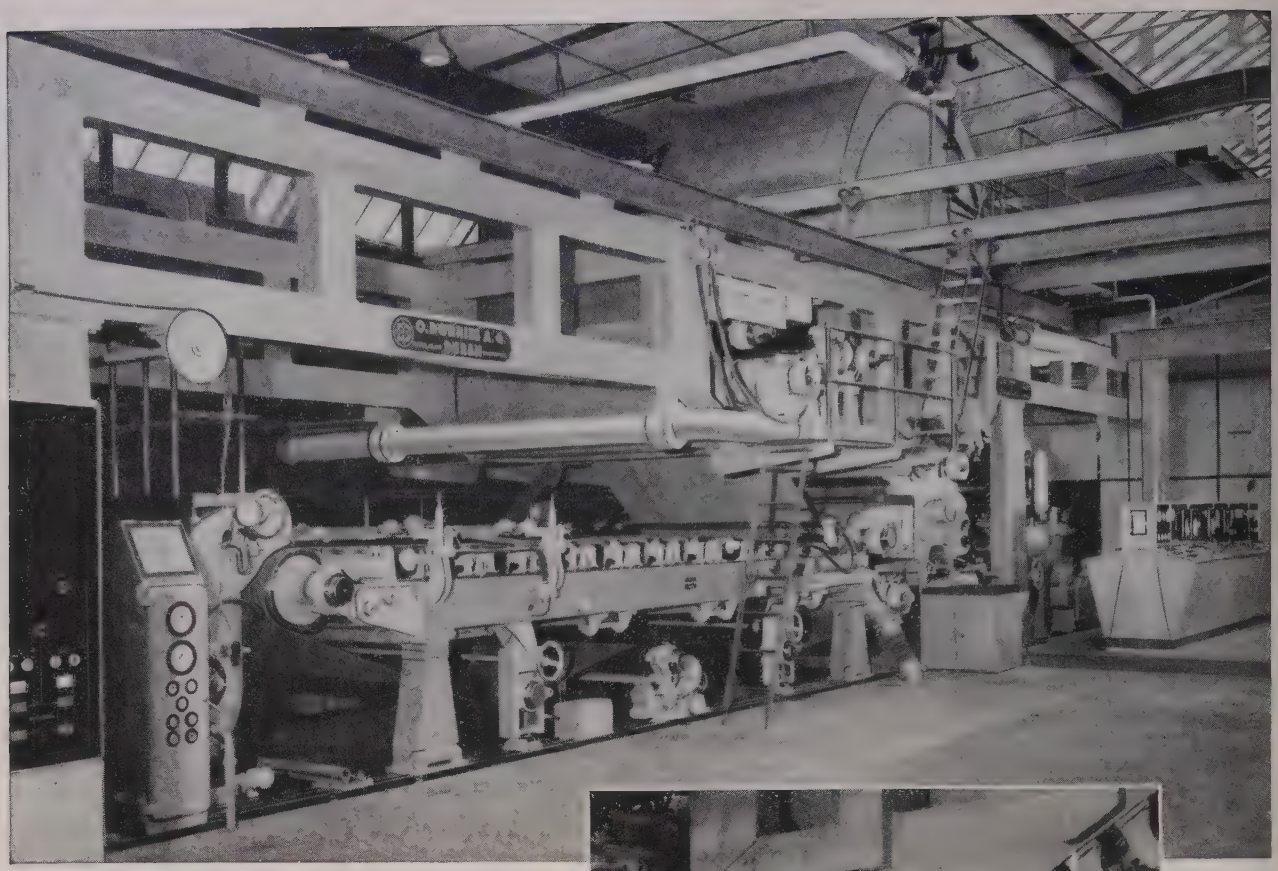
When you look through a speeding roll of carbon paper, the slightest defect in the wax used will show up quickly. Wax, the vehicle for the ink, is the essential ingredient in the ultra-thin carbon paper made by the Kling Manufacturing Company, of Chicago. Their customers, manufacturers of "unit sets," insist on high quality.

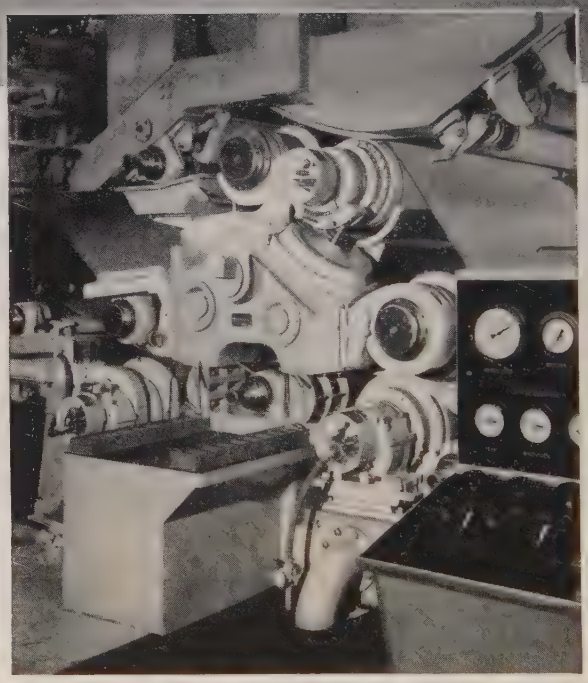
Eight years ago Kling chose Cities Service Pacemaker 53 Wax. Because they compete with larger national companies, they must offer their customers superior quality and fast service. "You can see," says Plant Superintendent Frank Orlow, "that our quality control is a direct result of the wax we use."

If you want to see a quality wax in action, try Pacemaker 53 Wax. Call your nearest Cities Service office or write: Cities Service Oil Company, 60 Wall Street, New York 5, N. Y.

CITIES SERVICE

QUALITY PETROLEUM PRODUCTS





Precision

also in the field of paper machine engineering

This modern automatic pick-up machine is suitable for the production of pulp wadding, sanitary papers, tissue towels and light weight M.G. papers.

Special characteristics:
Fully automatic operation of the whole machine from a control desk.
Special equipment for a quick change of wires, felts and doctors.

O. DÖRRIES A.G. DÜREN

Eisengießerei und Maschinenfabriken · Western Germany

Agents: Bulkley, Dunton Pulp Company, Inc. 295, Madison Avenue, New York 17 N.Y./USA
Telephone: Murray Hill 9-6400 Telex: TWY - NY 1 - 2092

Bright idea in paper...

Turning a paper container into a pirate ship is a fun-idea. But the idea uppermost in the minds of paper makers is producing whiter, brighter, stronger papers. Including coated paper containers, moisture-resistant enough to sail the wildest creek!

Yes, paper makers are constantly devising new ways to make paper better. And Becco is working hand-in-glove with them.

Just recently, for example, we installed the Becco Refiner Bleacher Process in three mills producing cold soda pulp. This process produces a quality pulp and, because of its simplicity, saves on actual processing costs while increasing output per unit of space.

Could your paper benefit from Hydrogen Peroxide? Becco, with more years of bleaching experience than any other H_2O_2 producer, would be happy to be of service to you. Just write us, describing your fields of interest. Address: Dept. T-61-12.

BECCO Hydrogen Peroxide

Putting Ideas to Work

fmc FOOD MACHINERY AND CHEMICAL CORPORATION ®

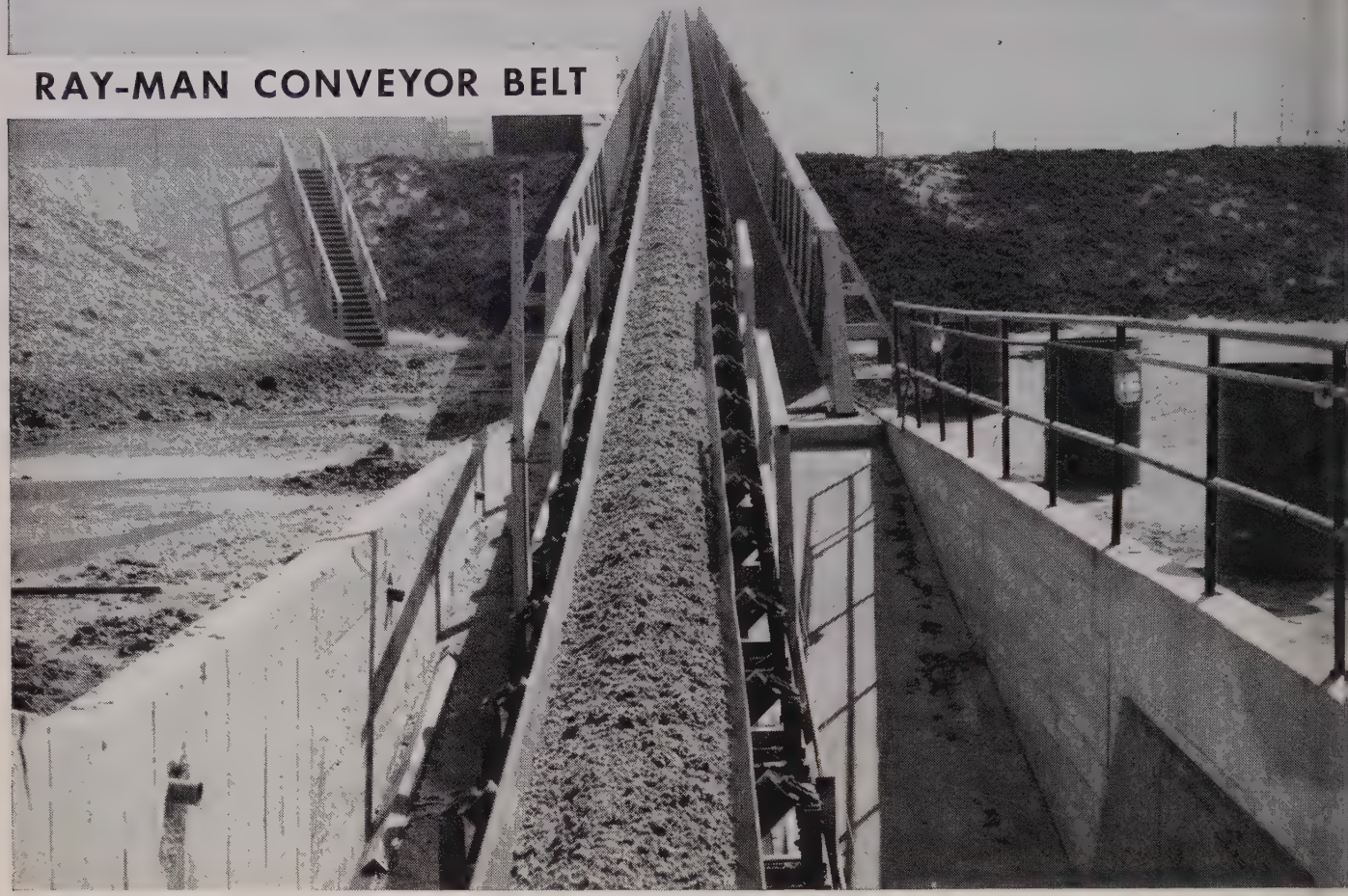
FOOD MACHINERY AND CHEMICAL CORPORATION

Becco Chemical Division

General Sales Offices:

161 EAST 42nd STREET, NEW YORK 17, N.Y.

RAY-MAN CONVEYOR BELT

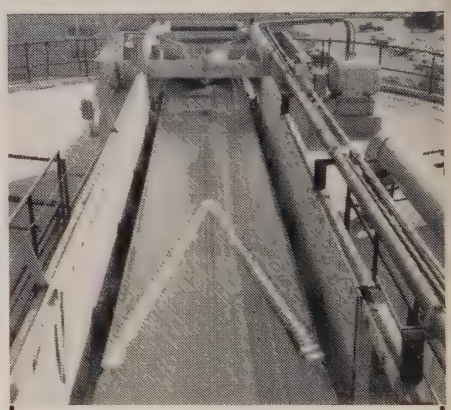


RAY-MAN Troughs Deeper, Trains Easily ...For Highest Pulp and Chip Capacity

Ray-Man conveyor belt and 45° idlers provide pulp load capacity at this Crown-Zellerbach Pacific coast paper mill. Consider these advantages of Ray-Man for your conveyors:

- **High Cover-adhesion All Around**—top, bottom, and edges
- **Full Cover Thickness Used**—no breaker needed, longer cover life
- **Splices Last Longer**—holds fasteners better
- **More Troughable and Trainable**—highly flexible, double Compensated
- **Designed for 45° Idlers**—guaranteed against separation at idler hinge line
- **Operates on Smaller Pulleys**
- **Impact Cushioned**—resists ripping

Ray-Man is mildew-proof and moisture resistant . . . can be made oil-proof for use with chippers. Ask your R/M distributor about Ray-Man or about log conveyors. Write for Bulletin M303.



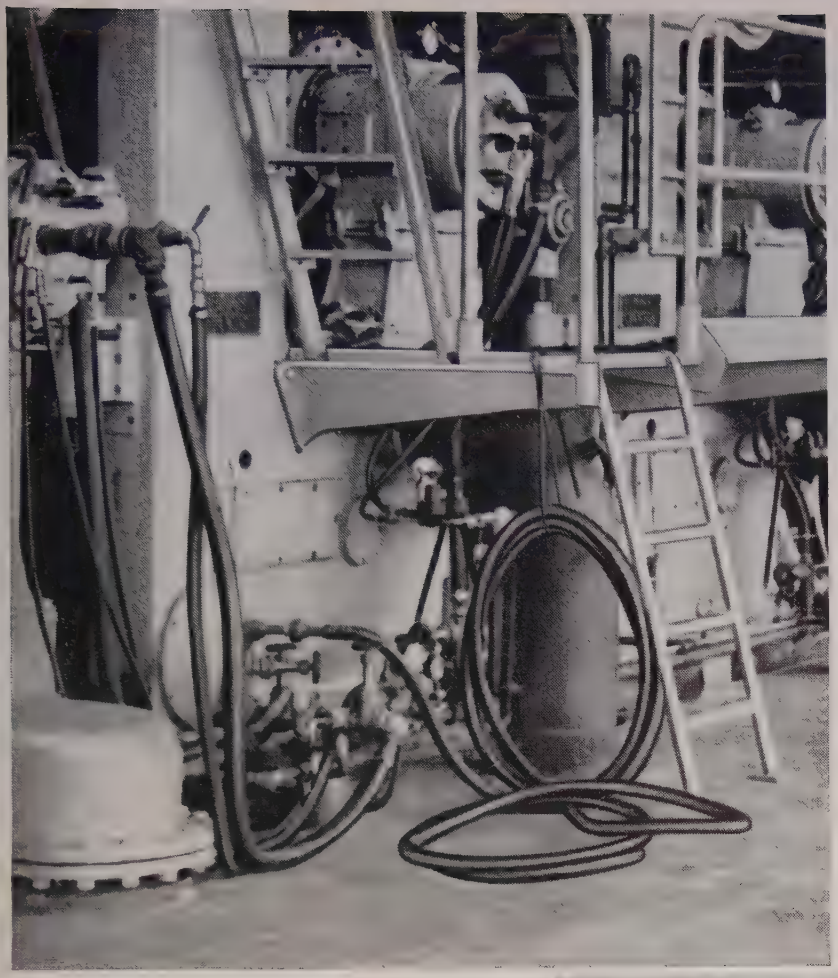
R/M'S PATENTED WEDLOK SPLICE Provides Dependable, High-Tension Mechanical Splice with a Vulcanized Splice-Rating on Ray-Man Conveyor Belts at Crown-Zellerbach. Get "More Use per Dollar" . . . Save Time and Money with Wedlok Splice. Write for Bulletin M380.

RM-108

RAYBESTOS-MANHATTAN, INC.

MANHATTAN RUBBER DIVISION • PASSAIC, N. J.

ENGINEERED RUBBER PRODUCTS



HOMOFLEX Paper Mill Hose Is Light . . . and Flexible as a Rope

Homoflex is the easiest handling wash-down hose made and weighs less than any other hose for equal working pressure.

- **Super-Strong** — assures longer, trouble-free service life
- **Precision Built**—Homogeneous construction provides inseparable tube-to-cover bond
- **Kinkless**—coils and uncoils freely in any direction
- **Mandrel-Made**—no pre-set twist
- **Safer, Easier Coupling** — inside and outside diameters are uniform
- **Available With Built-In Tapered Rubber Nozzle**—prevents machine damage

Write for Catalog M5.

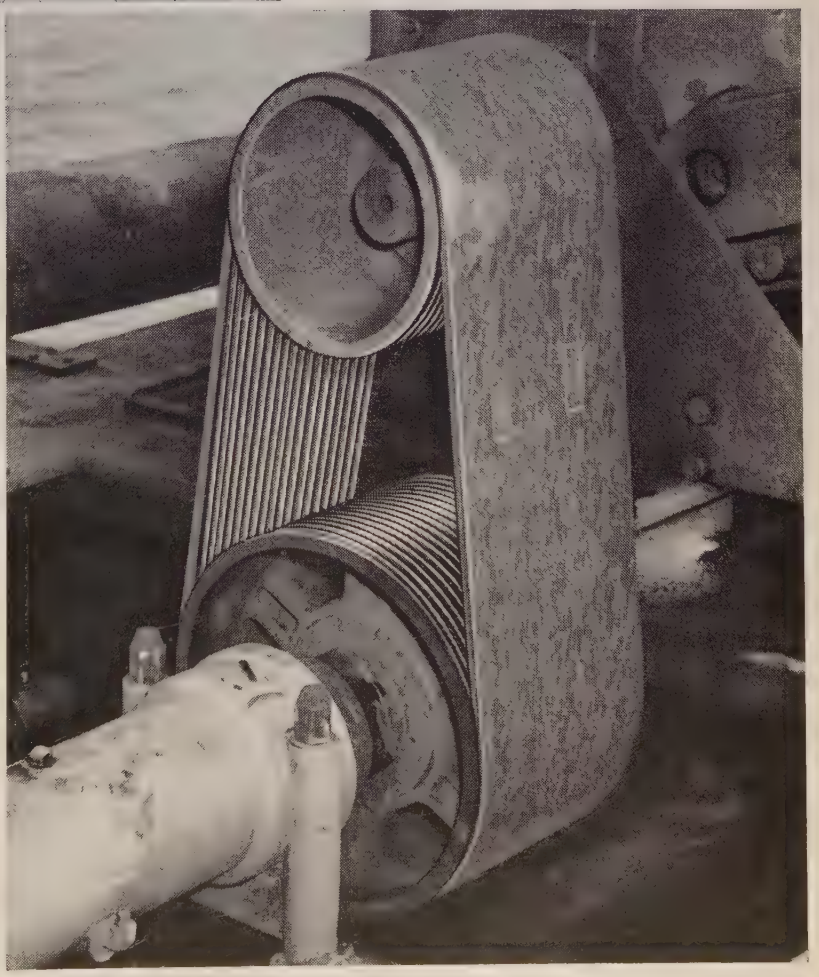
R/M POLY-V® Drive Delivers More Power in Less Space . . . with More Reliability

A single, endless V-ribbed belt across full width of sheaves with mating grooves. Gives more power per inch of width and advantages never possible with conventional multiple belt drives.

- **Simplicity**—*two* belt cross sections meet *every* heavy duty requirement
- **Reliability**—less maintenance, less take-ups . . . longer belt and sheave life
- **No Matching**—single unit belt eliminates "length matching"
- **Better Performance** — maintains groove shape, constant pitch and speed ratios . . . runs smoother, cooler

WHEN YOU CHANGE DRIVES CONVERT TO POLY-V* . . . AND BE SURE.
Write for Bulletin M141.

*patented



Paper Sculpture by Robert R. Jackson

Paper takes to water better, with Uformite

Good wet strength, plus processing advantages and overall economy, are combined in Rohm & Haas UFORMITE® wet strength resins.

Whether you need wet strength for toweling, bag paper, napkins, paperboard, wrapping paper, or specialty items, there's a UFORMITE resin designed to give good results at a reasonable cost. You also get excellent storage stability, ease of handling (no acid pretreatment needed), and easy broke recovery.

Technical information on use of UFORMITE resins is available on request. Ask for the booklet, "UFORMITE *Resins for Wet Strength Paper.*"

Advantages of individual resins:

UFORMITE 700—high off-the-machine wet strength without the broke recovery problems caused by other types of resins.

UFORMITE 711—efficient all-round performance at low cost.

UFORMITE 467—maximum economy in unbleached papers.

ROHM & HAAS

PHILADELPHIA 5, PA.

UFORMITE

magic wand cuts packaging costs by upgrading cheap chipboard into SALESMEN for your product

GLIDDEN ZOPAQUE® LD-C

Made especially for the paper industry, a new anatase grade TiO_2—GLIDDEN ZOPAQUE *LD-C*—combines the best features of anatase and rutile grades for paper coating.

GLIDDEN ZOPAQUE *LD-C* gives you the better brightness of anatase TiO_2 with the ease of dispersion and low viscosity features of rutile grades.

QUALITY Glidden PRODUCTS

THE GLIDDEN COMPANY

FINEST PIGMENTS FOR INDUSTRY

Chemicals Division • Pigments and Color Department

Baltimore 26, Maryland

SEE OTHER SIDE FOR MORE INFORMATION

GLIDDEN ZOPAQUE® LD-C

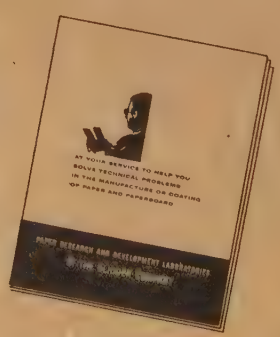
new anatase grade titanium dioxide gives properties of rutile, savings as much as 2¢ per pound

SEE SAMPLE ON OTHER SIDE OF THIS PAGE

New GLIDDEN ZOPAQUE *LD-C* is equally suited for on and off machine, size press and calender coating. It is compatible with all other common paper coating adhesives and pigments.

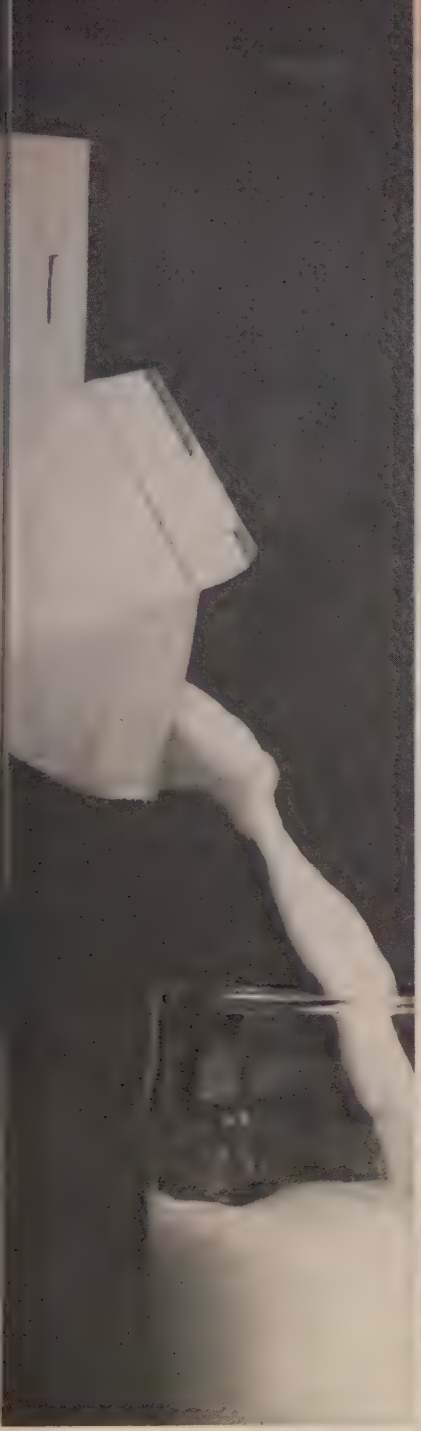
Being an anatase grade TiO_2, new *LD-C* is for coating all nonwaxing, plain and printed paper and board. Higher machine speeds, heavier coating weights and other advantages are inherent in new *LD-C*. For technical information or samples, call your Glidden representative or write address below.

NEW BROCHURE—*Paper Research and Development Laboratories* describes the many Glidden technical facilities now at your service for development or testing work in paper. Just off the press.



QUALITY Glidden PRODUCTS

THE GLIDDEN COMPANY
FINEST PIGMENTS FOR INDUSTRY
Chemicals Division • Pigments and Color Department
Baltimore 26, Maryland



If they're made with A-C Polyethylene, they have more gloss, strength, and resistance to scuff and water

turdier dairy cartons. Cartons coated with A-C® Polyethylene-araffin blends can withstand rough handling. Leaking, flak-ng and bulging are virtually eliminated. Smooth plastic-like eel, pleasant to the touch.

o more "fiber scratch." Wax coatings for appliance and fine rniture cartons, made with A-C Polyethylene, avoid "fiber cratch"—and the need for costly liners.

Super-high gloss for food wraps. A-C Polyethylene imparts *super*-high gloss to waxed paperboard, often makes over-wrappings unnecessary. Ideal for frozen food, ice cream, bread wrappers.

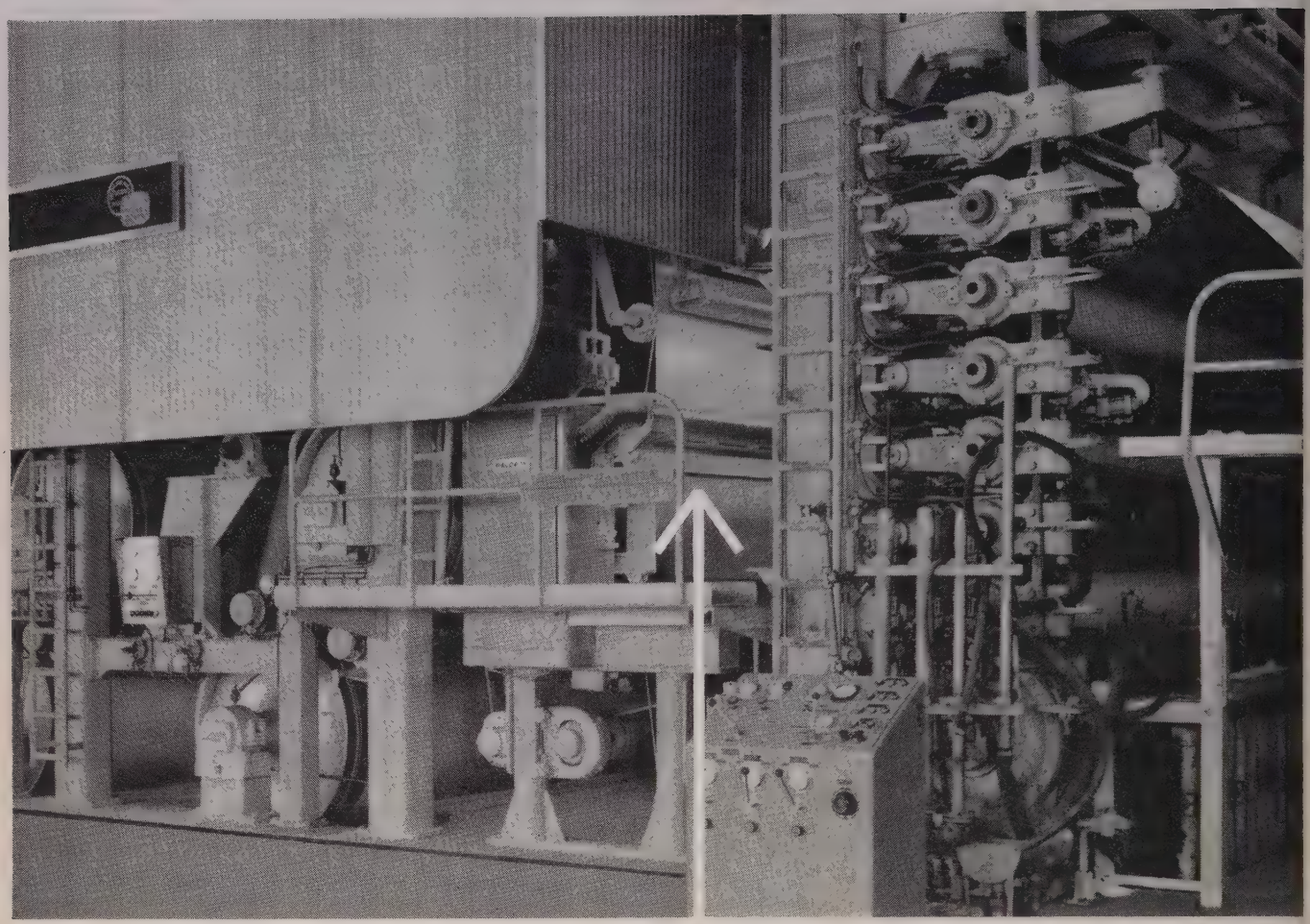
To get better packaging, specify A-C Polyethylene. To make better packages, use A-C Polyethylene. For more information, write us today for complete details.

PLASTICS DIVISION

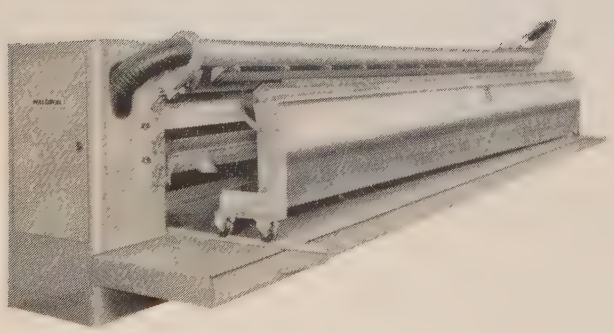
DEPT. 611-T, 40 RECTOR ST., NEW YORK 6, NEW YORK
IN CANADA: ALLIED CHEMICAL CANADA, LTD., MONTREAL

Allied Chemical

BASIC TO AMERICA'S PROGRESS



Here's the best place for a Microjet® coater



On the paper machine shown above the Waldron Microjet coater provides an accurately metered film of coating for printability or functional properties on paper and board surfaces at high speed. The proven Microjet air doctor applies coatings on smooth pre-coated or rough uncoated surfaces with a higher efficiency than any other coating method and gives uniform and economic control of coating weight over a wide range. The coater is available for on-machine or converting operations, either as a unit or as a complete installation with all associated mechanical and Ross drying equipment.

The experience of more than a hundred machines in operation provides Microjet users with the best production-minded machine in the industry. For additional information write for bulletin 1010. Complete laboratory facilities in our plant for coating and drying commercial equivalent products are available to you.

WALDRON

technical competence in web process machinery

WALDRON-HARTIG, Box 791, New Brunswick, N. J./a division of Midland-Ross Corporation MR

V-10 now also in water soluble bags.

No need for a proportioning pump.

No expensive metering devices.

Makes accurate and clean addition of V-10 to control slime.

Vineland's V-10 . . . bis-1, 4-bromacetoxy-2, butene; a perfect slime controllant.

Proven* safe for any ordinary use in tissue, wadding and food board mills. Helps reduce downtime.

Vineland's technical staff is ready to assist you in establishing proper slime control in your mill. Bacterial counts and identification of prevalent microorganisms will be determined without cost or obligation.

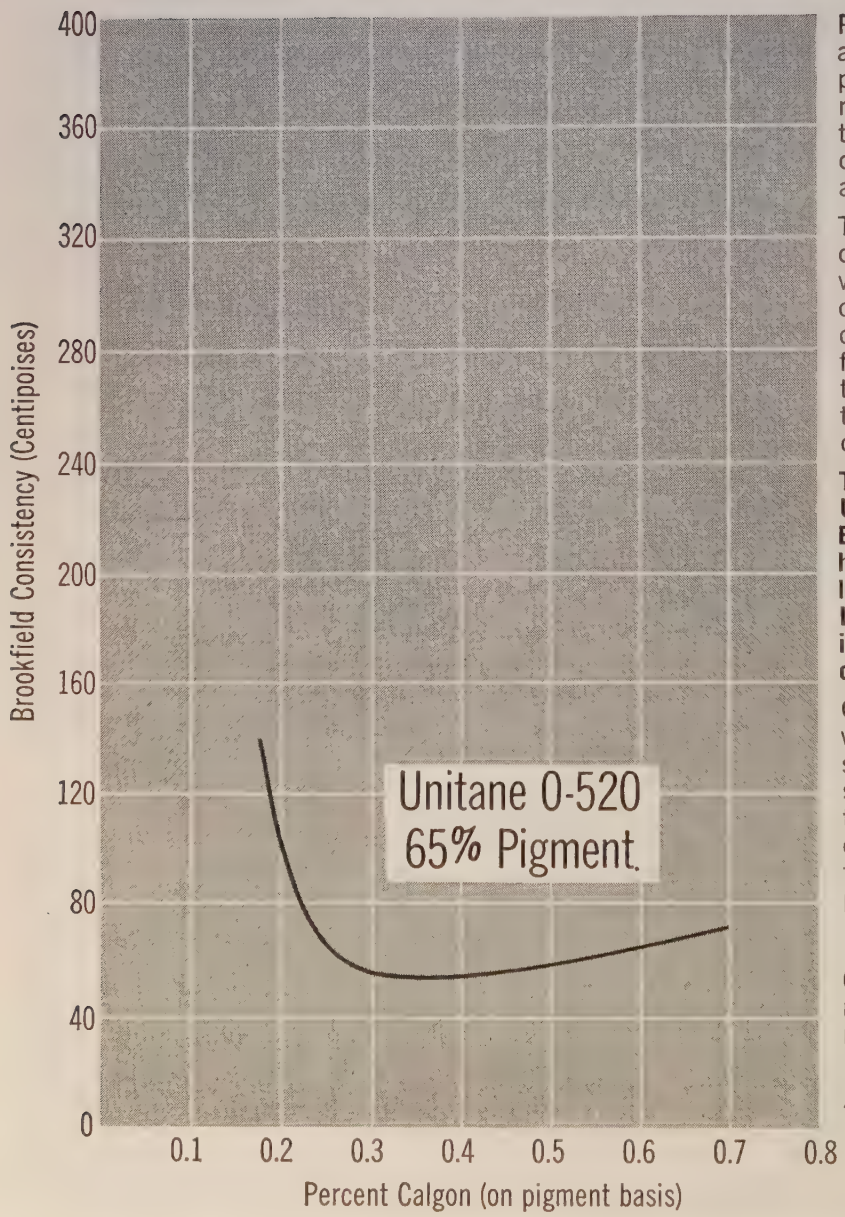
Write or telephone (OX 1-3535) for free booklet, "Control of Slime in the Paper Mill."

* *Test results available on request.*

Vineland Chemical Co.

West Wheat Road, Vineland, New Jersey

smoother, more economical paper coatings assured with new Unitane® 0-520



Recognizing the trend toward smoother and more economical paper coatings employing relatively mild dispersion techniques, Cyanamid has produced a new titanium dioxide pigment, Unitane 0-520 designed especially to meet the most exacting requirements of the paper coater.

The curve illustrates the low dispersant demand and low viscosity of coatings made with Unitane 0-520. The very slight increase in viscosity with increasing amounts of dispersant gives the coating formulator flexibility of formulation. It enables him to control deflocculation and to sequester the polyvalent ions from hard water, calcium carbonate and other fillers.

These desirable features are found in Unitane 0-520:
Easy to disperse — excellent response to high speed equipment • Low consistency — low water demand • High pigment loading • Low abrasion factor • Extremely low residue (325 screen) — promotes smoother coatings

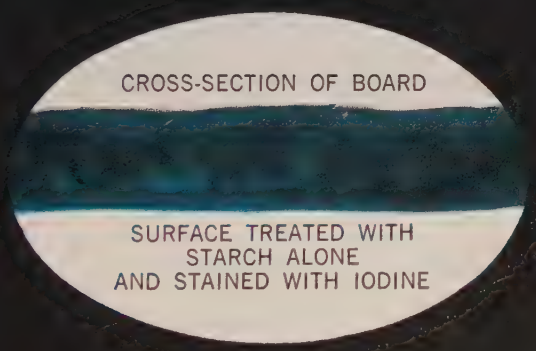
Comparisons with Unitane 0-110, a type well-known in the paper industry, have shown that the new Unitane 0-520 has the same good opacity in all coating applications. A comprehensive report of the tests on Unitane 0-520 and the currently offered paper coatings types has been prepared and is available from your Cyanamid Pigments representative. Why not call him now and let him show you how Unitane 0-520 can give you smoother, more economical coatings. A generous sample is ready for your tests. *Whiter and Brighter with Unitane*

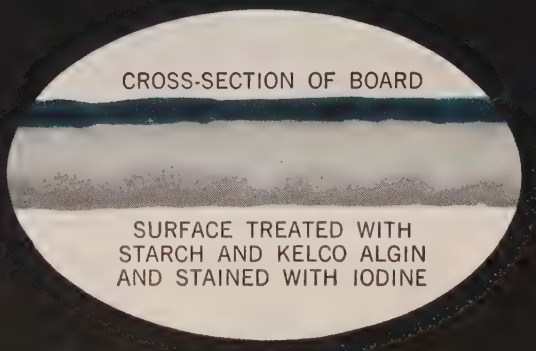
CYANAMID

AMERICAN CYANAMID COMPANY PIGMENTS DIVISION
30 ROCKEFELLER PLAZA, NEW YORK 20, NEW YORK

SEE HOW THESE PHOTO-MICROGRAPHS PROVE...

KELCO ALGIN PRODUCTS CONTROL PENETRATION



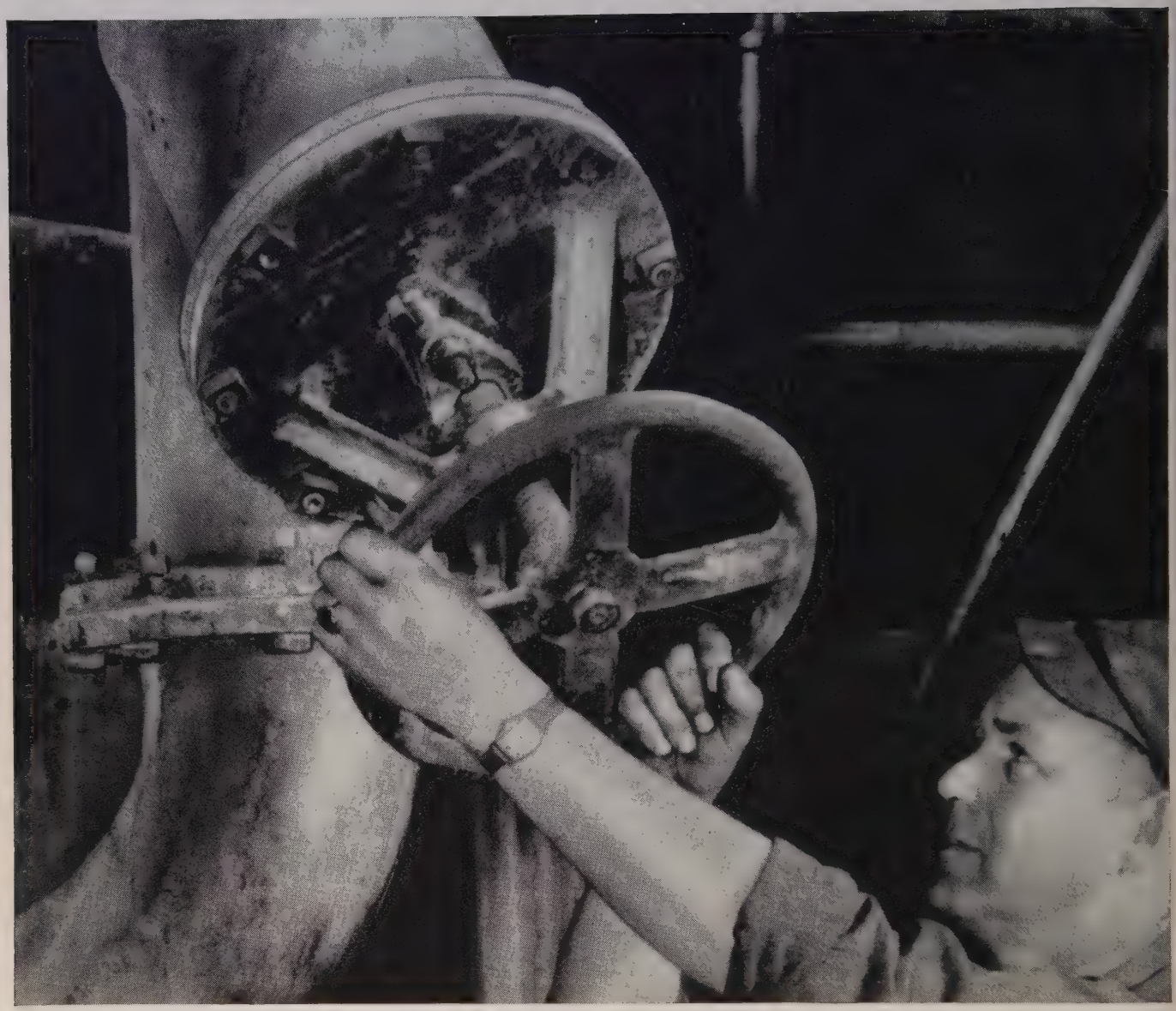


These unretouched photographs show greatly magnified **cross-sections** of two pieces of board: One surface sized with starch alone; the other sized with starch and Kelco algin. See how the starch has saturated through the entire paper on which it alone was used. But what a difference when starch is combined with Kelco algin. This combination remains on the surface, proving beyond question that algin **with** starch controls penetration and strike through. For, with unique Kelco colloids you regulate surface density and penetration, precisely and effectively. This is a positive, reliable fact, providing benefits that are well worth test and evaluation in your own operation.

YOURS ON REQUEST: Technical data and assistance by Kelco's highly trained technicians. Without obligation, call or write your nearest Kelco regional office.

Kelco Algin products of KELCO COMPANY

75 Terminal Avenue, Clark, New Jersey • 20 N. Wacker Drive, Chicago 6, Illinois
530 W. Sixth Street, Los Angeles 14, Calif. • Cable Address: KELCOALGIN – CLARKNEWJERSEY



In pulp mill hot acid system

Cast nickel stainless steel "Y" valve . . . resists corrosion for 31 years, is still trouble-free

After 31 years of service on a digester relief line handling hot sulphite liquor, steam and hot SO_2 gas, this cast stainless "Y" valve is as good as the day it was installed.

And this cast valve is expected to give many, many more years of trouble-free service . . . despite operating temperatures up to 270°F and operating pressures up to 50 psig.

Long life cast in. To assure a long service life right from the start, the valve was cast in an alloy equivalent to Type CF-8M* (19% Chromium, 10% Nickel, 2.5% Molybdenum).

This nickel-containing casting alloy provides a high degree of corrosion resistance and strength, making it an ideal choice for valves and pumps that must withstand the constant attack of a variety of corrosive materials throughout industry.

An entire family of cast austenitic nickel stainless alloys is available today to give you equipment that will resist corrosive attack, protect your product against contamination, and deliver long, low-maintenance service.

To help you select the right nickel-containing casting alloy, we've prepared a detailed 72-page booklet: "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications". Just drop us a note requesting Booklet A-266. A copy will be sent to you immediately.

*A.C.I. designation

THE INTERNATIONAL NICKEL COMPANY, INC.

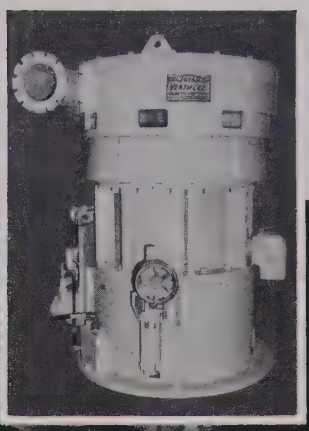
67 Wall Street INCO New York 5, N. Y.

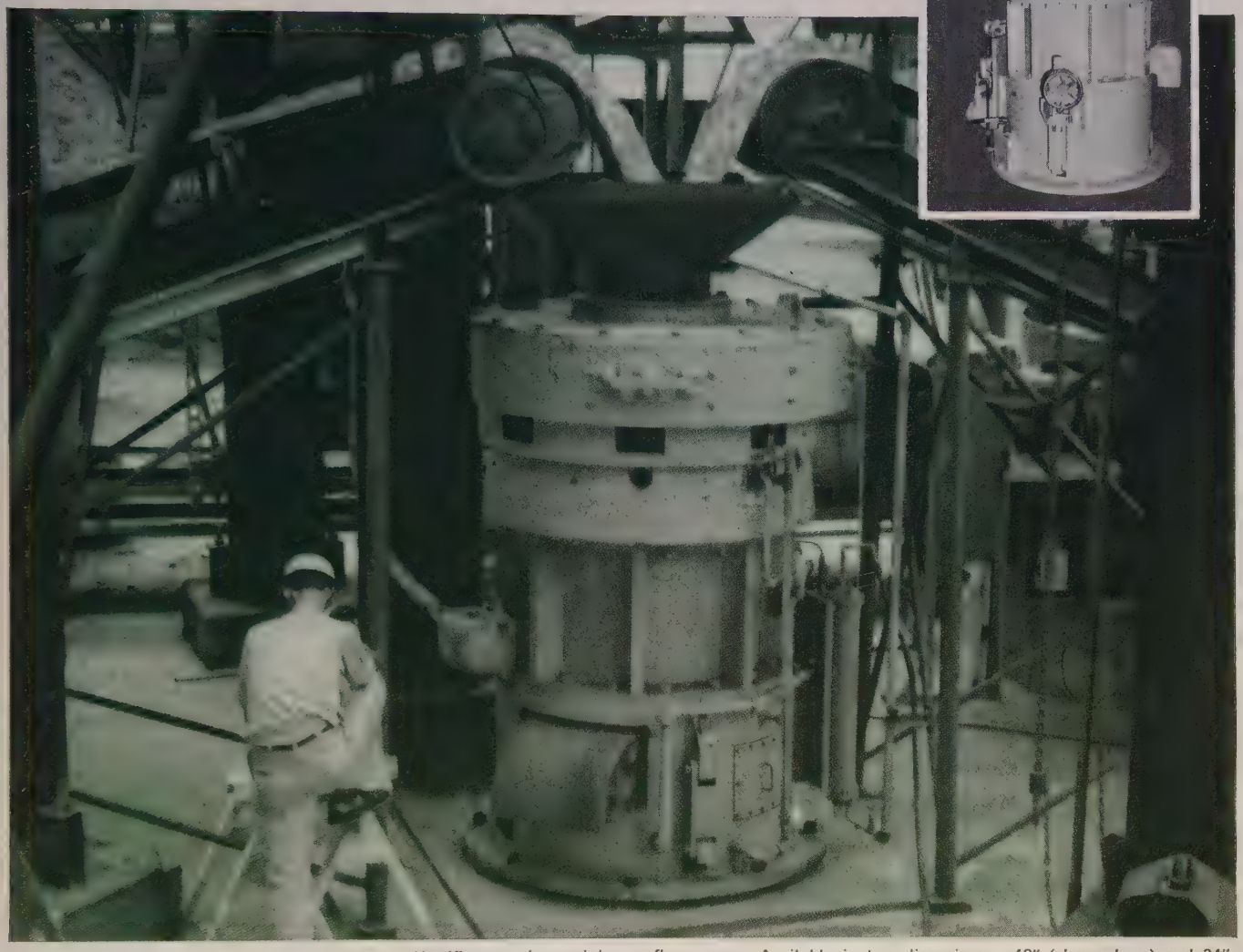
INCO NICKEL

NICKEL MAKES ALLOYS PERFORM BETTER LONGER

For primary refining at low power . . .

New Jones Vertiflex®





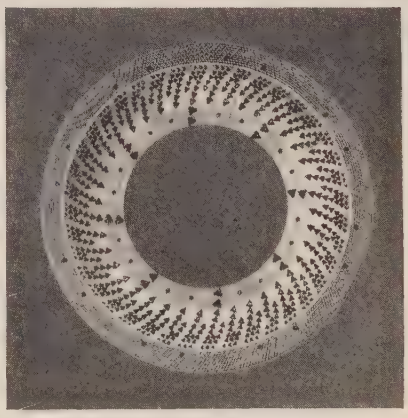
Vertiflex requires minimum floor space. Available in two disc sizes — 48" (shown here) and 34".

Typical application . . . . . Chip Shredding

High quality pulp with extremely low waste and fibre damage, substantial savings in alkali used, increased yield, decreased screen rejects and lower recovery system loading — those are the results from this efficient Jones Vertiflex chip shredding installation. And energy required to process more than 2000 B.D. tons per day is just over ¼ HP days per ton!

Full size chips are fed to the Vertiflex by belt conveyors from two chip silos. Resulting "shreds" are as long as the original chips, but greatly reduced in cross section.

Other applications on which the Jones Vertiflex will perform with outstanding efficiency include cold caustic chips, high yield pulps, bagasse, high density bleaching and denoodling. For full details write to E. D. Jones Corporation, Pittsfield, Mass.



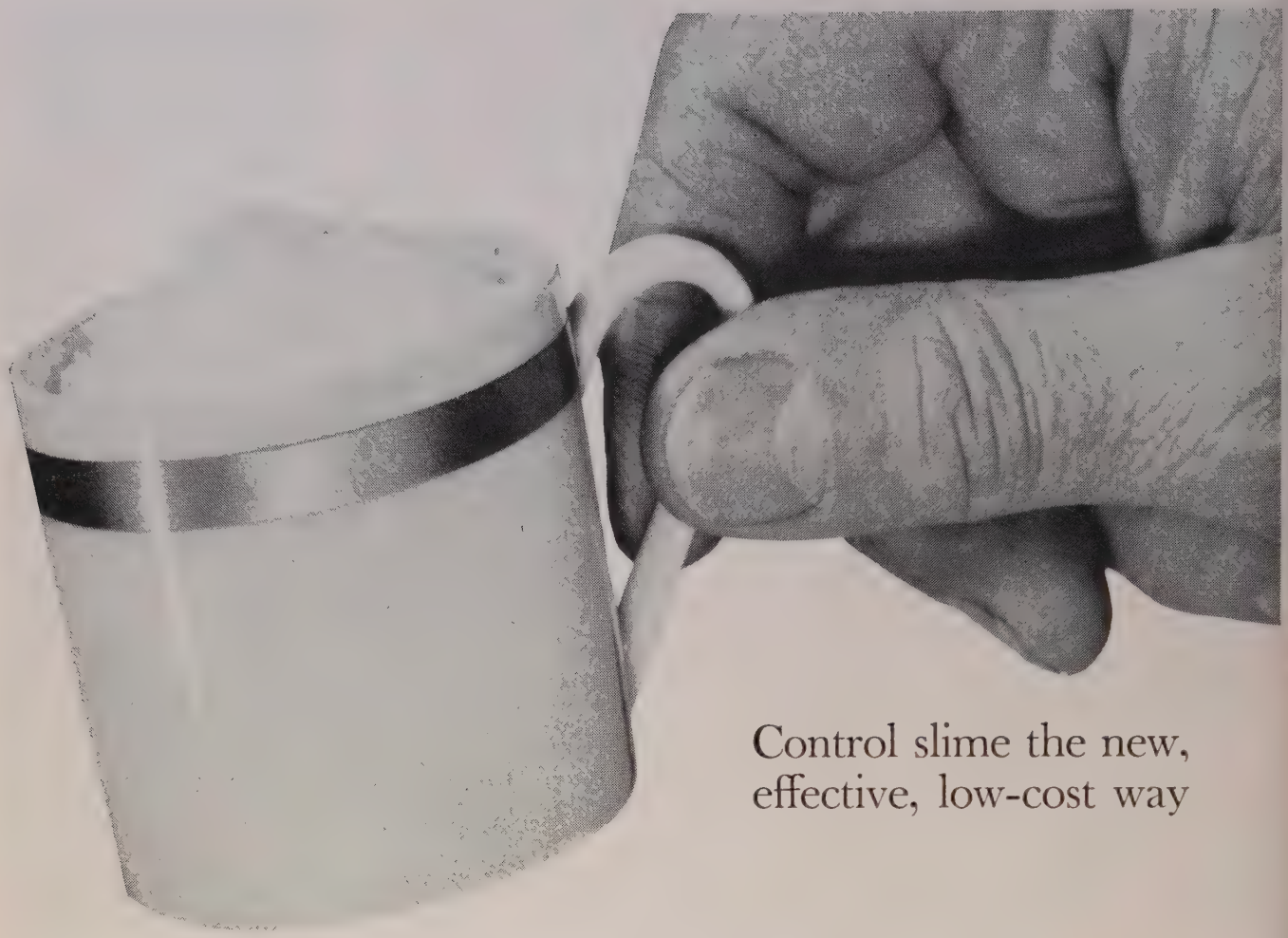
Teeth in vertically mounted rotating disc inter-mesh with teeth in opposing stationary plate mounted in Vertiflex cover. Clearance is easily adjustable and disc life is high since there is never any metal-to-metal contact. Teeth shape and arrangements are varied to fit the application.

E. D. JONES CORP. member BELOIT group PITTSFIELD, MASS.

Jones

PULP MILL EQUIPMENT AND STOCK PREPARATION MACHINERY

Represented in Canada by
The Alexander Fleck Ltd.
75 Spencer Street, Ottawa



Control slime the new, effective, low-cost way

Just this much C2® slimicide for a ton of pulp!

- Newsprint
- Unbleached, semi-bleached and bleached kraft
- Food and paper board
- Printing and book papers

EFFECTIVE. Extensive mill use proves conclusively that C2, the new Mathieson slimicide, is the most effective product for acidic white water systems. Only ¼ pound of C2 per ton of pulp (often even less) is a common dosage rate for rapid, sustained control. Actual cost per ton: about 10-20¢. Resultant action: continuous generation of chlorine dioxide throughout the white water system . . . a distinct advantage over other slimicides which function only near point of application.

Other C2 advantages: no foaming at the head box . . . will not darken pulp . . . will not affect dyes at recommended dosage rates.

EASY-TO-USE. C2 is readily soluble in water and is non-corrosive to equipment.

C2 is shipped in highly-soluble, dry-flake form in quantities from one-pound samples to 100-pound drums in truckloads and carloads. Also, 50% solution is supplied in tank cars and trucks.

FDA CLEARANCE. C2 is our trademark for sodium chlorite. The Food And Drug Administration has expressed the opinion that this chemical is not a food additive when used as a slimicide as it cannot reasonably be expected to become a component of food through this use.

See C2 work in your mill—call for a demonstration.

Olin Mathieson, Baltimore 3, Maryland

CHEMICALS DIVISION Olin

164

felt facts

Recognize these men? They're among the top executives, designers, chemists, and service and sales engineers who plan, edit and contribute to Albany Felt Company's FELT FACTS.

The experience and skills of these men are made available to the paper industry through this eight-times-a-year publication which has won the respect of papermakers everywhere.

Readers tell us they depend upon the authoritative information about paper machine felts detailed in FELT FACTS. This comes from the number of key men who participate in making this publication an informative, accurate, technical reference work. As such, FELT FACTS can and does assist papermakers in producing more tons per day, more days per felt.

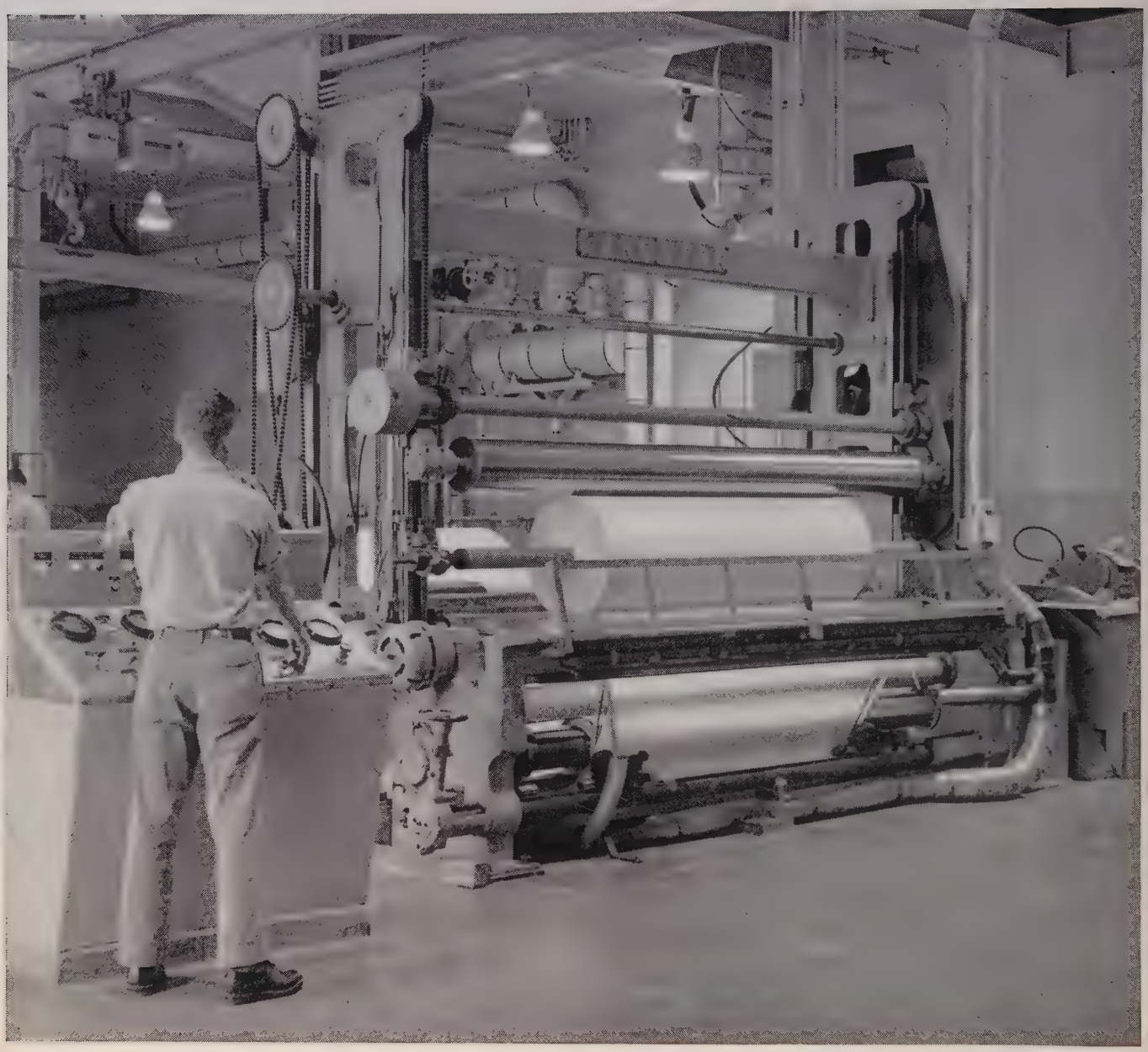
Clockwise, by groups from left are: Laurence M. Woodside, Chief Eng., Tech. Field Services, and S. Stuart Engle, Tech. Director. John S. Sweet, Ass't. Chief Chemist; Carl C. Gordon, Chief Chemist, and Z. J. Chagnon, Div. V. President. Thomas O. Tietz, Adv. Mgr.; David F. McConaughy, Ass't. Chief Designer; W. S. Wightman, Ass't. Chief Designer; Harold F. Hedberg, V. President, Research, and James E. Smith, V. President and Gen. Mgr., Albany Felt Co. of Canada, Ltd. Samuel Van Praag, Sales Mgr.; Wayne G. Davis, V. President, Felt Sales, and James Garofalo, Service Eng.

ALBANY FELT COMPANY
ALBANY, N.Y.

Dedicated to Paper Industry Progress

N. Monmouth, Maine Hoosick Falls, N. Y. St. Stephen, S. C.
Cowansville, Quebec Cuautitlan, Mexico

TALK FELT FACTS WITH YOUR ALBANY FELT SALES ENGINEER



Want uniformly wound, scratch-free rolls of fine paper? Call Langston

Every type of paper has its own special winding requirements. This is why Langston offers winders with so wide a variety of features—why you can get the exact winding results you want, for your particular weight, grade and finish of paper.

The two Langston winders recently installed at Hurlbut Paper Co. (subsidiary of The Mead Corporation), at South Lee, Mass., were built to handle fine specialty papers. Instead of standard, fixed-type spreaders, Langston used rotating-type cambered spreaders. They not only eliminate scratches, but insure clean separation of the rewound rolls.

Operators like the easy operation of these machines. From a convenient console, they can operate practically all controls, including automatic constant sheet tensioning, automatic roll ejection, winder speed, and lateral adjustment of back stand.

What are your special requirements in a winder? Langston can engineer a winder to meet them. Write for information. Samuel M. Langston Co., 6th and Jefferson Sts., Camden 4, N. J.

Langston LEADERSHIP . . . BY DESIGN

A SKILLED HAND IN CHEMISTRY . . . AT WORK FOR YOU

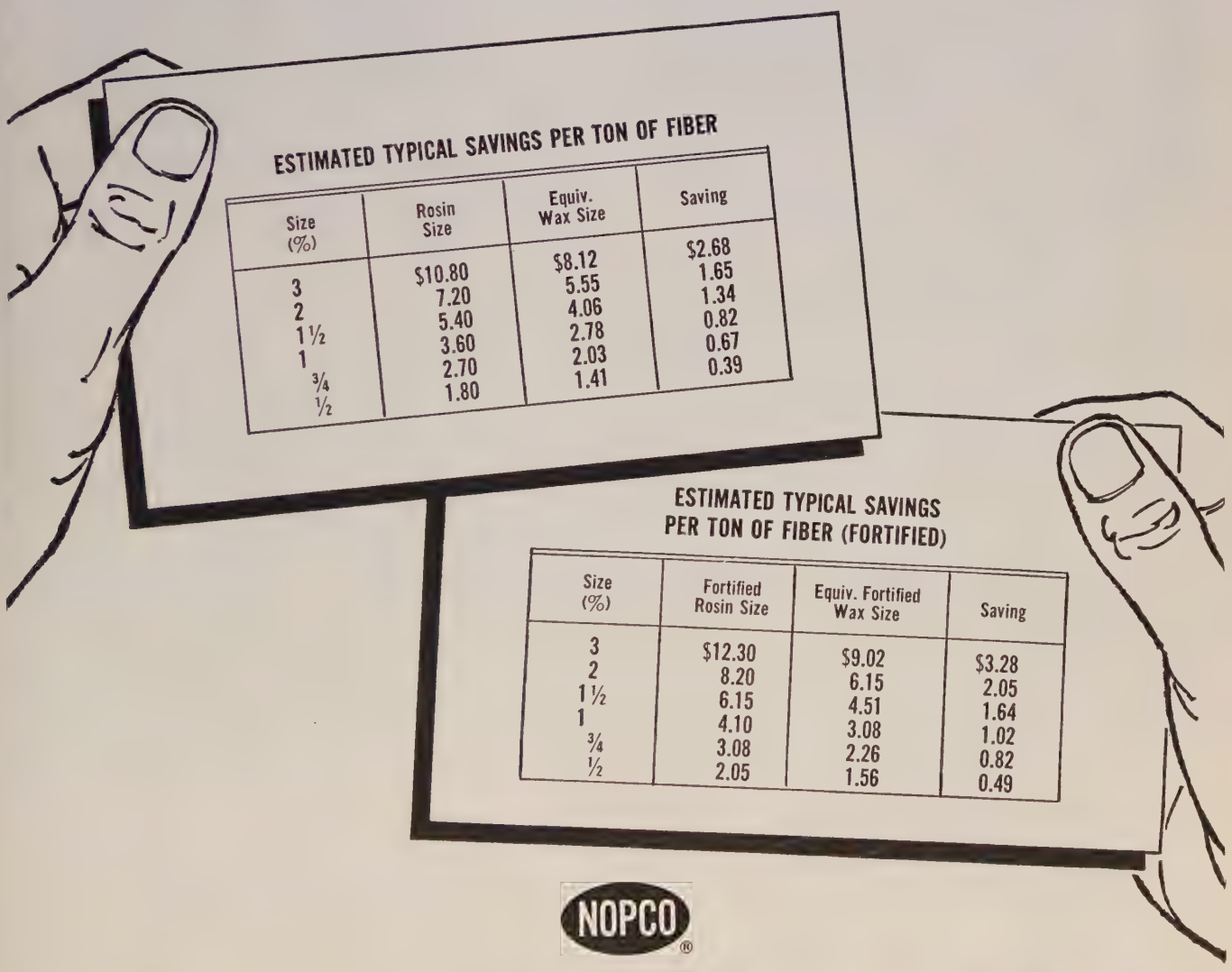
Are your rosin size costs too high?

Nopco® Wax Sizes do more—cost less

Whether your mill uses rosin or fortified-rosin sizes, Nopco can show you how to reduce your sizing costs by using its wax sizes. In addition to saving you money, Nopco Wax Sizes impart improved resistance toward water, ink, lactic acid, alkalis and blood; improve gloss, smoothness and printability; and decreases fuzz, curl and brittleness.

Use of Nopco Wax Sizes in your mill is an advantage you cannot afford to overlook. Let us help you set up a program of tests and trial runs to prove it to your own satisfaction.

Our Technical Service Engineers, utilizing over 30 years' experience with wax sizes, are ready to show you the advantages to be gained by the use of wax sizes in conjunction with rosin sizes. Write today for further information.


ESTIMATED TYPICAL SAVINGS PER TON OF FIBER
Size (%) | Rosin Size | Equiv. Wax Size | Saving
3 | $10.80 | $8.12 | $2.68
2 | 7.20 | 5.55 | 1.65
1½ | 5.40 | 4.06 | 1.34
1 | 3.60 | 2.78 | 0.82
¾ | 2.70 | 2.03 | 0.67
½ | 1.80 | 1.41 | 0.39
ESTIMATED TYPICAL SAVINGS PER TON OF FIBER (FORTIFIED)
Size (%) | Fortified Rosin Size | Equiv. Fortified Wax Size | Saving
3 | $12.30 | $9.02 | $3.28
2 | 8.20 | 6.15 | 2.05
1½ | 6.15 | 4.51 | 1.64
1 | 4.10 | 3.08 | 1.02
¾ | 3.08 | 2.26 | 0.82
½ | 2.05 | 1.56 | 0.49

NOPCO®

NOPCO CHEMICAL COMPANY

60 Park Place, Newark, New Jersey

Plants: Harrison, N.J. • Carlstadt, N.J. • Richmond, Calif. • Cedartown, Ga. • London, Canada • Mexico, D.F. • Corbeil, France

Manufacturing Licensees Throughout the World

The KADY® MILL

COATING COLOR

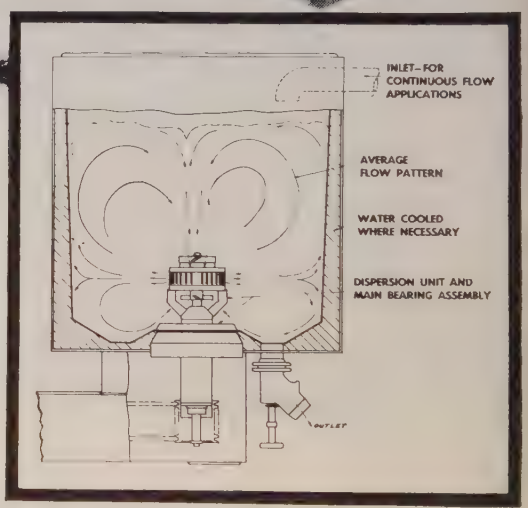
in

MINUTES

instead of

HOURS

- ★ **Cook Protein, Casein or Starch in presence of pigment efficiently and economically.**
- ★ **Color for Machine or Off Machine coating in one operation.**
- ★ **Low Viscosity with high solids.**
- ★ **Reduce Binder percentage.**
- ★ **Develops optimum opacity and gloss.**



Over 50 paper plants have approved the advantages and economy of coating color production by the KADY method. The uniformity of viscosity, optimum value from Ti 0_2, calcium carbonate, satin white and from whichever adhesive or combination of adhesives used, prove the superiority of the KADY method to any other.

If you want continuous processing or have a color system deaerating problem to overcome, let us give you the complete story of KADY applications to suit your specific requirements. Many quality control problems on all types of coaters are being solved effectively, color application improved and superior finish obtained by a simple, low cost installation of a KADY MILL!

** Pictured above is the 200 gallon model 4BH-60. Other models, including the new T series, in capacities from ½ to 750 gallons.*

KADY® proven best in WORLD WIDE installations:

- United States
- Canada
- England
- Norway
- Sweden
- Finland
- Denmark
- Germany
- France
- Belgium
- Japan
- Mexico

British Commonwealth (except Canada)
Steele & Cowlishaw, Ltd.
Stoke-on-Trent, England
and
Continental Europe:
Kady International (Europa) N.V.
Raamgracht 4
Amsterdam, Holland

Convenient Lease or Time Payment Plan

Kinetic Dispersion corp.
Buffalo, N. Y. 95 Botsford Place

fmc®

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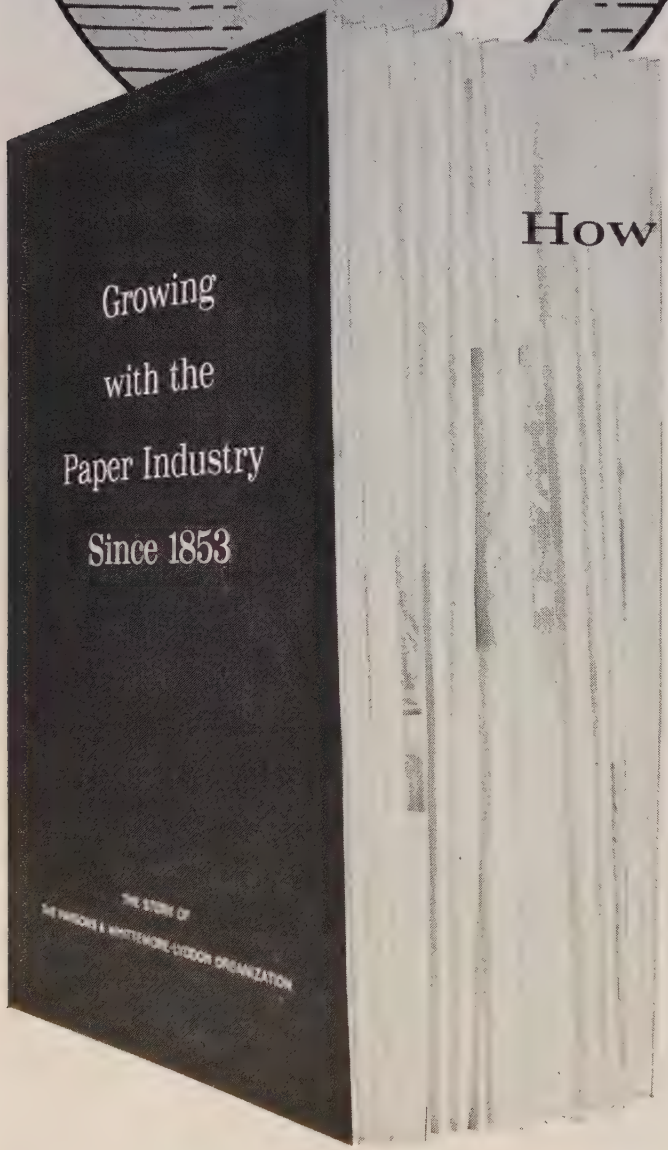

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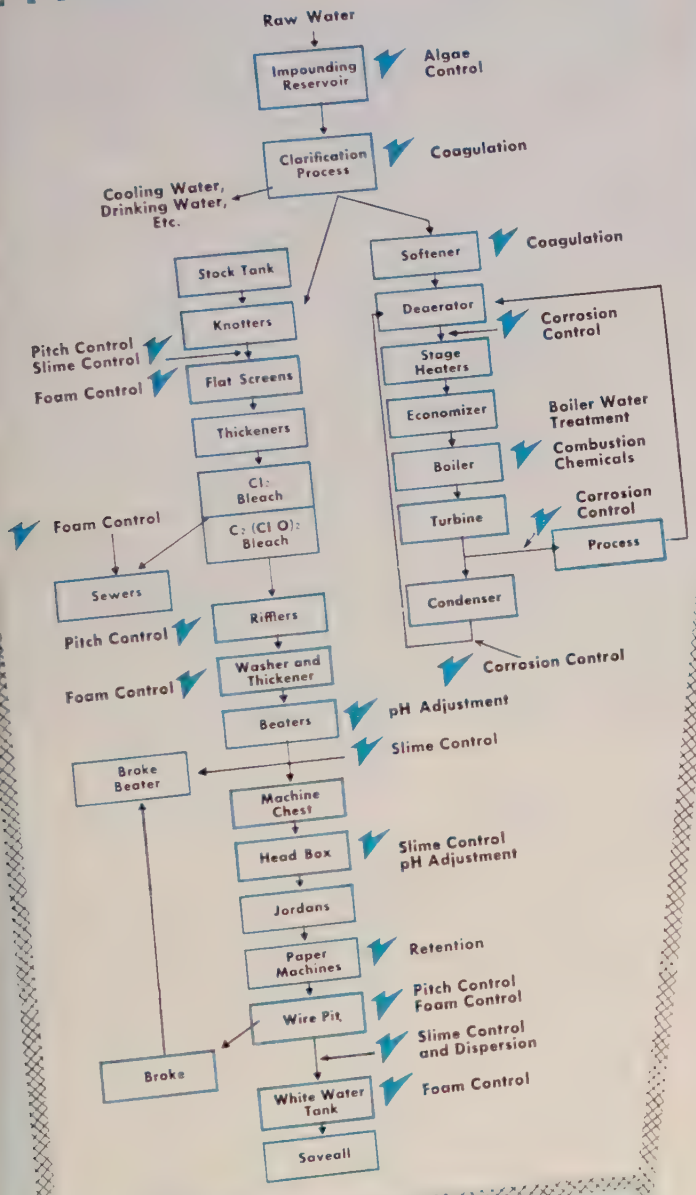

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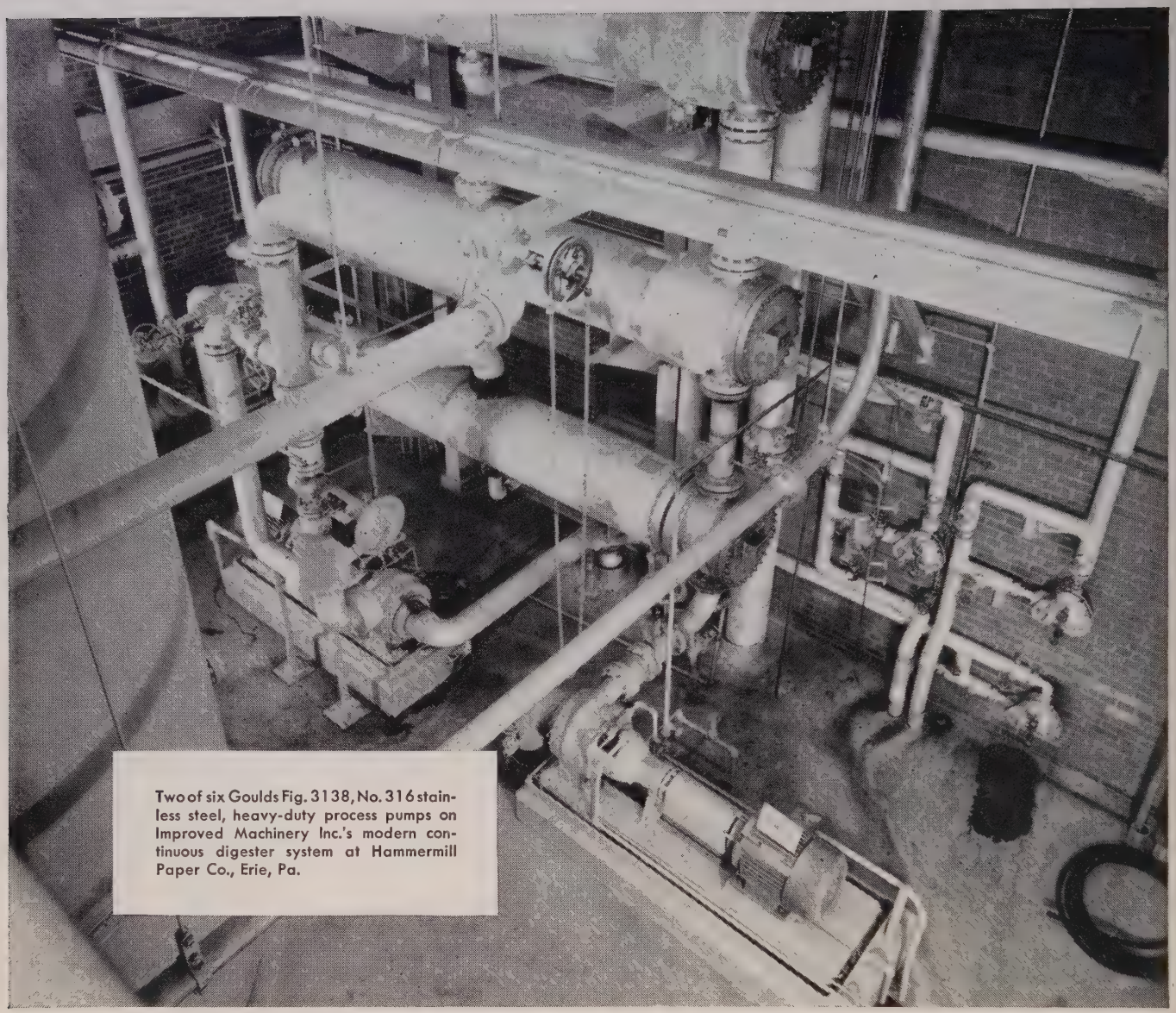

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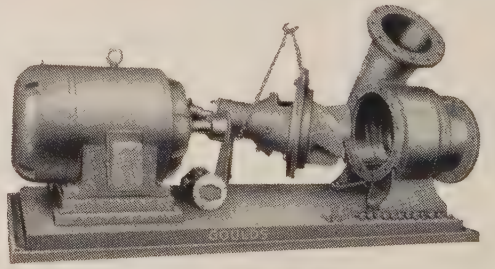

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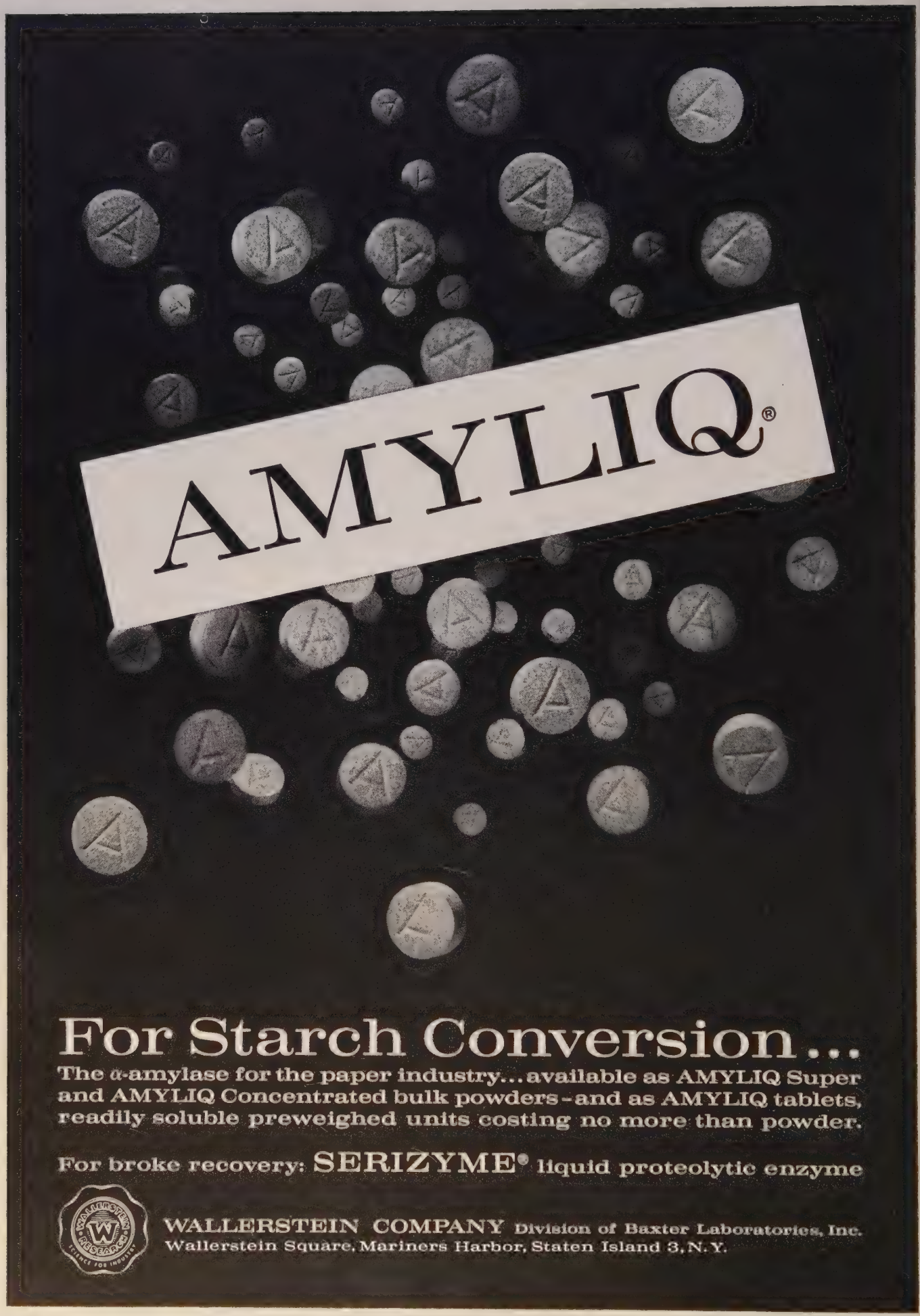

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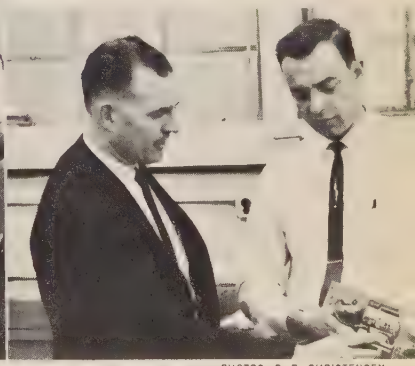

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The Commercial Production of Acetic and Formic Acids from NSSC Black Liquor

W. A. BIGGS, JR., J. T. WISE, W. R. COOK, W. H. BAXLEY, J. D. ROBERTSON, and J. E. COPENHAVER

To eliminate its neutral sulfite semichemical (NSSC) black liquor stream and air pollution problem, Sonoco Products Co. has operated, since June, 1958, the world's first chemical plant for the commercial production of acetic and formic acids from pulp mill black liquor. The process consists of the concentration of the black liquor to 40–45% solids, followed by approximately stoichiometric acidification with H_2SO_4 to liberate the acetic and formic acids from their sodium salts; this acidified liquor is solvent-extracted countercurrently with 2-butanone to recover the acids; the mixed acetic and formic acids are separated by azeotropic distillation with ethylene dichloride; both acids are refined for sale—the acetic product being glacial (99.5+%) and the formic product being 90% acid. The raffinate from the extraction is sold to kraft mills for its salt cake value. Startup and operational problems have been numerous and equipment corrosion proved to be very serious on most of the refining equipment. The economics of the overall process integration are discussed with particular emphasis on the utility of such a process in improving the economics of cross-recovery between NSSC and kraft mills.

To ELIMINATE its NSSC black liquor pollution problem, Sonoco Products Co. has operated, since June, 1958, the world's first chemical plant for the commercial production of acetic and formic acids from pulp mill black liquor.

This chemical recovery plant is a key unit in a large expansion program at our pulp and paper mill at Hartsville, S. C., whereby we have eliminated an intolerable public nuisance with the expectation of increased company profit from the recovery operation. This benefit has been realized because an increase in our nine-point corrugating board production, from 150 to 350 tons per day, has been made possible while all the pulp-plant effluent is recovered and converted into chemicals for sale. This major expansion is the culmination of 10 years of research into an economical means of black liquor disposal and putting an end to this most serious source of stream and air pollution. A great deal of pioneering has gone into this effort in the pulp plant, paper mill, and chemical recovery, and all our problems are not solved. The recovery plant is not yet self-sustaining economically. We have every confidence, however, that it will be soon.

This paper gives a background of this development, describes the Sonoco Chemical Recovery Process for the first time, points up some of the problems encountered, and evaluates the significance of the development for the future in the paper and chemical industry.

W. A. BIGGS, JR., Group Leader, Chemical Research and Development, J. T. WISE, Senior Chemist, Chemical Research and Development, W. R. COOK, Senior Chemist, Chemical Research and Development, W. H. BAXLEY, Supervisor, Chemical Recovery, J. D. ROBERTSON, Senior Chemist, Chemical Research and Development, and J. E. COPENHAVER, Chief Chemist, Chemical Research and Development, Sonoco Products, Co., Hartsville, S. C.

BACKGROUND

At Hartsville, Sonoco operates one of the very first hardwood, NSSC mills ever installed, on a black-water stream known as Black Creek, on the edge of the City Limits. Since 1933, this mill has produced nine-point corrugating board. Until 1958 the production rate was 150 tons per day on one fourdrinier machine. In addition, the company has produced continuously, on eight cylinder machines, about 400 tons per day of board from wastepapers.

The white water from all these operations was returned to Black Creek, which has an average stream flow of about 200 million gallons per day. The B.O.D. from this amount of white water, along with other plant effluents, was about all the stream could tolerate while sustaining fish life. As a consequence, NSSC black liquor had to be disposed of by pumping to lagoons located a mile or so from the plant in a sandhill, wooded area.

Unfortunately, the liquor in these lagoons fermented badly during the warmer half of the year, producing very foul odors which were especially obnoxious to the whole urban and rural area. In addition, the lagooned black liquor, still containing a large part of the original B.O.D., percolated through sandy soil back to Black Creek.

THE NATURE OF NSSC BLACK LIQUOR POLLUTION

Our NSSC pulping has been principally from black gum, sweetgum, and tupelo hardwoods with relatively minor amounts of poplar, elm, oak, etc. Cooking is carried out to give yields in the range of 80%, and the black-liquor–dissolved solids have a B.O.D. of about 400,000 p.p.m. (dry solids basis) or about 300 lb. of B.O.D. per ton pulp. Approximately 50% of this B.O.D. is due to sodium acetate and sodium formate. The remainder is due to wood sugars, fats, and resins. The lignin sulfonates do not appear to make any significant contribution to the standard five-day B.O.D. Table I gives a typical solids analysis of these black-liquor solids.

The quantities of sodium acetate and formate shown in Table I are equivalent, respectively, to 18.2 lb. of acetic acid and 2.04 lb. of formic acid per 100 lb. of solids. With a total dissolved solids in the black liquor of 740 lb. per ton of pulp produced, these quantities amount to 134 lb. of acetic acid and 15 lb. of formic acid per ton of pulp produced. If these acids could be removed economically, the pollution problem could be reduced by 50%, or looked at another way,

Table I. Sonoco NSSC Black Liquor—Typical Solids Composition

	Parts by weight
Sodium lignin sulfonates	56.0
Fats and resins	4.0
Pentose sugars	10.0
Hexose sugars	1.5
Sodium acetate	25.0
Sodium formate	3.0
Sodium butyrate	Trace
Calcium oxalate and sulfate	0.5
	100.0

pulp production could be doubled without increasing the B.O.D. problem above the existing level.

We also reasoned that the residual black liquor, after organic acids recovery, might be disposed of to nearby kraft mills for its salt cake content, if sulfuric acid was used to liberate the organic acids from their sodium salts thereby forming sodium sulfate in equivalence. In this way, it appeared that we might be able to "have our cake and eat it too." We were aware of the fact that the simplest means (theoretically) of eliminating the black liquor B.O.D. and air pollution problem was to burn the liquor in a recovery furnace and recover as much inorganic chemical for re-use as possible.

Nothing concrete was in evidence then (1950), which might be called a practical, proved NSSC total recovery process. At the same time, our extensive pilot operations on biochemical oxidation of our effluents did not look promising economically. As a consequence, we began a market survey on acetic acid, formic acid, and salt cake.

MARKET POTENTIAL FOR ACETIC ACID, FORMIC ACID, AND SALT CAKE

Production

In 1952, the U. S. Tariff Commission figures showed that about 400 million pounds per year of glacial acetic acid was produced in the United States at a market price of $0.08 per pound, and about 11 million pounds of formic acid (100% basis) at $0.16 per pound. At the same time, it was found that about 600,000 tons of salt cake (sodium sulfate) was produced per year at a price of $27.00 per ton (100% basis) with a constant rise in the production curve. In the case of salt cake, it was apparent at once that freight costs to consumer was the all-important consideration.

Consumption

Acetic acid holds about the same relative position in the organic field that sulfuric does in the inorganic. Its use is very basic and widespread in industry. Table II shows the consumption in 1945 (*1*). The formic acid consumption (*2*) is given in Table III.

Table II. U.S.A. Acetic Acid Consumption in 1945

	Lb.
Direct military	28,971,000
Foreign	536,000
Plastics and resins	175,240,000
Acetic anhydride	146,896,000
Esters	116,439,000
Textile processing	24,812,000
Drugs and pharmaceuticals	7,485,000
Metallic acetates	7,416,000
Paints and pigments	3,497,000
Rubber chemicals	1,994,000
Photography	1,417,000
Miscellaneous	32,274,000
Total	546,977,000

Table III. U.S.A. Consumption of Formic Acid in 1953

	Lb.
Textile dyeing and finishing	8,450,000
Metallic salts	2,625,000
Leather industry	2,000,000
Esters	770,000
Miscellaneous	1,555,000
Total	15,400,000

Salt Cake. By far the largest consumer of salt cake is the kraft industry, which uses three fourths of the annual production. Next in importance is the detergent industry, where from 50 to 75% of the powdered detergent bought by the housewife is reported to be sodium sulfate (*3*). At the time of this survey, the kraft industry was using 500,000 tons of salt cake per year, mainly in the southeastern United States.

Existing Sources

Acetic Acid. Until World War II, virtually all acetic acid, other than vinegar grade, was produced as a product of the destructive distillation of hardwoods. Charcoal was a principal product, with methanol a by-product. The acetic yield per ton of dry wood was about 100 lb. This is about the same yield as that available in NSSC black liquor on the same basis.

In recent years petrochemical processes have displaced wood distillation as the main source of acetic acid; it is made through acetaldehyde from propane and butane, or by the oxidation of petrochemical ethanol.

Today less than 5% of the total acetic acid production is from wood distillation; and that as a by-product of charcoal manufacture. Edible vinegar grades of acetic acid, which are produced by fermentation, have not been considered because of the rigorous requirements of the Food and Drug Administration.

Formic Acid. Formic acid is produced mainly by the acidification of formamide with sulfuric acid, which yields a mole of formic and a mole of ammonium sulfate, and by a like acidification of sodium formate, a by-product of the manufacture of pentaerythrital.

Sodium Sulfate. This chemical is too well known to the paper industry to discuss the sources here in any detail. A principal production is, of course, from hydrochloric acid manufacture. Much is produced in the viscose rayon industry and a considerable amount is available in the West from natural sources. Some is imported from abroad. One of the nearest sources for the kraft industry in the Southeast has been from viscose rayon production.

PROCESS DEVELOPMENT

The foregoing market studies encouraged us to go ahead with exploratory research aimed at finding a practical method of recovery of these pulp mill by-products for sale in such a manner that our black liquor could be completely disposed of economically.

Sonoco Products Co. because of its central South-

Table IV. The Aqueous Concentration of Acetic Acid in Acidified NSSC Black Liquor (20.7% Acetic Acid on the Solids)

Solids, %	*Acids, %*	*Water, %*	*Acid concn. in water, %*
10	2.07	90	2.25
20	4.14	80	4.91
30	6.21	70	8.15
40	8.28	60	12.10
50	10.35	50	17.15
60	12.42	40	23.70
70	14.49	30	32.60
80	16.56	20	45.40

eastern location near both the kraft and textile industries, and its already extensive chemical manufacturing operations, seemed in a good position to exploit black liquor chemical recovery, both organic and inorganic.

Esterification

This is the simplest of all methods of recovering acetic and formic acids from black liquor. One need only concentrate and then acidify the liquor, add an alcohol, and distill in a suitable distillation column with reflux control such as to bring overhead the desired ester. The ester can be purified to commercial grade by washing with water and redistilling. This gives mixed acetic and formic esters of the alcohol used, but these can be separated by distillation. The esterification reaction for acetic acid is:

$$ROH + CH_3COOH \rightleftharpoons CH_3COOR + H_2O$$

We carried this process all the way to pilot plant, making ethyl- and butyl acetates and formates, but then abandoned it because of the close margin between the cost of purchased alcohols and the sale value of esters therefrom, up to the amyl esters; both usually sell at the same price per pound. In addition, we found that the synthetic ketone solvents were displacing the acetate esters to a very considerable extent in the largest market—the paint, varnish, and lacquer field.

Recovery of Acetic and Formic Acids by Direct Distillation

Direct distillation of the acids from acidified liquor is not practical. This is due to the fact that the desired acids in the acidified liquor are so dilute with respect to the water content (see Table IV) at a practical total solids level, and because the vapor–liquid equilibria between boiling mixtures of acetic acid and water are such that the composition of acid in the vapor is never very different from the concentration in the liquid (see Fig. 1). Hence, virtually all the water must be distilled to recover the acetic acid. The demand for acetic acid at such dilute strengths is quite limited.

Azeotropic Distillation

Mixtures of acetic and formic acids in water can be concentrated to any desired degree by azeotropic distillation. To accomplish this one must have a volatile solvent which is nonreactive with the acids, does not hydrolyze in water, forms a binary azeotrope with water but not with the acids, has an azeotrope which boils well below 100°C., removes as much water as possible, and is reasonable in price. There are a number of these; for example, butyl acetate and methyl isobutyl ketone.

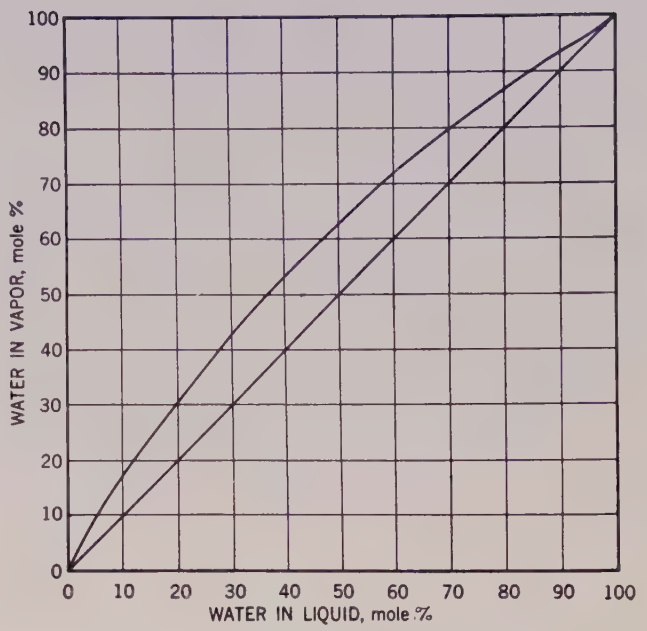

Fig. 1. Vapor–liquid compositions, acetic acid–water system

This method removes the water from the acids, leaving the acids in a huge volume of solids from which it is quite difficult and impractical to remove. Again, this method is very costly in steam. The Suida process (*4*) employs this method.

Solvent Extraction

Solvent extraction methods have been used for many years to recover acetic acid in concentrated form from its dilute aqueous solutions. It is the standard practice in the cellulose acetate industry and in acetic acid production from pyroligneous acid (wood distillation). It is by far the most economical approach in steam costs. Figure 2 is a typical flow sheet for an uncomplicated acetic acid extraction.

Numerous patents have been issued on solvent extraction processes, both here and abroad, based on the use of different solvents, equipment design and arrangement, etc., aimed at better purity of product or greater economy. The best known of these processes in the wood distillation field are Brewster (*5*), Coahran-Modified Brewster (*6*), and Othmer (*7*). These are the closest in application to acetic recovery

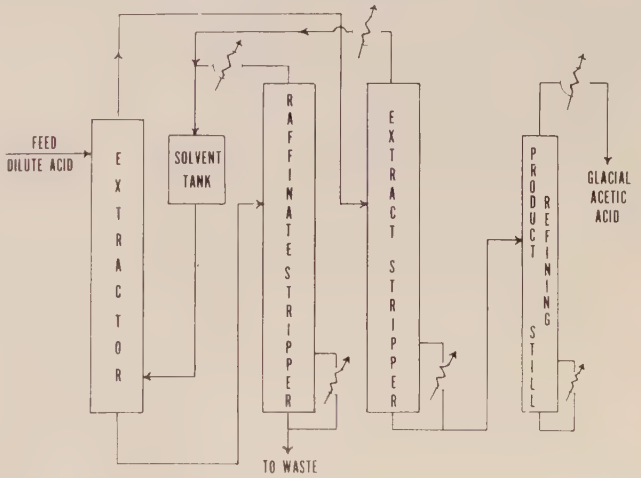

Fig. 2. Typical solvent extraction process for acetic acid

from black liquor. In these processes, only a few extraction solvents have proved useful; namely, ethyl ether, isopropyl ether, ethyl acetate, butyl acetate, and methyl isobutyl ketone.

THE SONOCO PROCESS DEVELOPMENT

When we began our laboratory studies of the solvent extraction, we did so using neutral black liquor concentrated from 25 to 60% solids, since it was obvious that multiple-effect evaporators could remove the bulk of the water from the 8 to 10% solids pulp plant effluent with the best steam economy. Furthermore, this would greatly reduce the volume of material to be processed and the size of any process equipment needed, as well as the volume of solvent required for extraction.

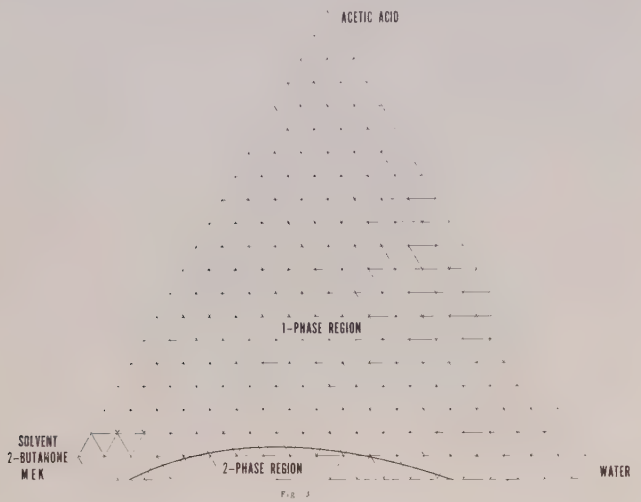

Fig. 3. Ternary equilibria; acetic acid-water-MEK system

We soon found that the well-known extraction solvents emulsified badly when in intimate contact with our sulfuric acid acidified liquor. This was true regardless of the temperature, up to just below the boiling point of the solvent and at all liquor-solids concentrations above 10%. These emulsions partially broke on long standing or by heavy centrifuging. It is important, however, to the efficiency of solvent extraction processes that the solvents be as immiscible as possible and that phase separation, after intimated mixing, be rapid and complete under normal gravity conditions. This led us on a protracted search for a practical solvent for use in our liquor system.

The following are the requirements of a useful extraction solvent for the black liquor system:

1. Low reciprocal solubility with water.
2. High partition coefficient for acetic acid in water.
3. Azeotrope with as much water as possible.
4. Nonazeotropic with acetic and formic acids.
5. Nonreactive with any component of the acidified black liquor.
6. Dissolve as little black liquor solids as possible.
7. Form no emulsion with acidified liquor.
8. Noncorrosive to materials of construction.
9. Reasonable in cost and commercially available.
10. Low toxicity.

We approached this complex problem by first searching the literature for azeotropic data on as many volatile organic liquids as we could find that had the proper range of properties for the system. These were evaluated in the laboratory. By the process of elimination we wound up with two solvents; namely, 2-butanone [methyl ethyl ketone (MEK)] and a mixture of 75% isopropyl acetate and 25% isopropyl alcohol. Interestingly enough, MEK has never been considered for acetic acid extraction because of its high reciprocal solubility behavior with water. At 23°C. the solubility of MEK in water is 26.3% by weight and the solubility of water in MEK is 12.6%.

The ternary equilibria (Fig. 3) between acetic acid, water, and MEK shows clearly why this solvent is a very poor choice for conventional solvent extraction of acetic acid.

In spite of all this, MEK proved to be highly efficient

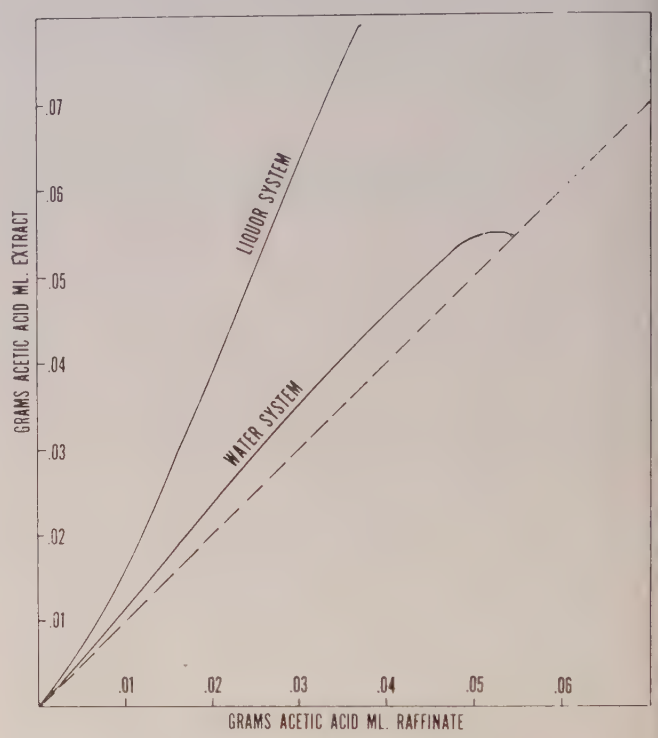

Fig. 4. Distribution of acetic acid between MEK and water

for acetic and formic acid extraction from acidified black liquor. The reason for this is that the sodium sulfate formed in the liquor solution on acidification, together with the sulfonated lignin, salts out most of the MEK from the water. If the liquor is concentrated to about 40% solids and then acidified, the system is just saturated with sodium sulfate, and MEK becomes highly efficient for acetic extraction. The partition coefficient is extremely good (see Fig. 4).

Our evaluation of the isopropyl acetate–isopropyl alcohol solvent combination did not measure up to that of MEK, although it is a useful combination, so we decided to concentrate further study on MEK. In the laboratory, we were able to carry out all the necessary extraction and distillation steps to produce glacial acetic acid and 90% formic acid. At this point we retained the services of the Engineering Division of Vulcan-Cincinnati, Inc., who had a great deal of experience in designing and building acetic acid plants.

Pilot-plant studies were carried out for each step of the process from liquor acidification through solvent extraction, solvent recovery, and acids refining. Corrosion studies were made in each step.

Cost studies were then made. These were dis-

appointing. We found that we would have an overly extended payout time, if the recovery plant was built to handle only the liquor volume from a 150-ton NSSC mill. Since the capital cost of a plant of this type increases as about the square root of the volume capacity increase, we saw that if our NSSC mill could be increased to about 300 tons of daily production we would have a favorable payout. The upshot of these studies was that we increased the mill size to 350 tons per day and built the recovery plant.

THE SONOCO RECOVERY PROCESS

Figure 5 shows a flow diagram of the Sonoco process. Dilute black liquor, *1*, at 8 to 10% solids is concentrated to 40% solids in triple-effect, forced-circulation evaporators *2*. The concentrated liquor is pumped to a surge tank, *3*, and from there through an agitated, in-line acidifier, *4*, where concentrated sulfuric acid is metered into and mixed thoroughly with the liquor. The acidified black liquor is passed countercurrently through the MEK–water binary azeotrope in the extractor *5* to solvent-extract the acetic and formic acids. The extract is fed from the extractor to column *6* where the MEK–water binary is distilled overhead, is condensed and recycled to the extractor for re-use. The bottoms from column *6* are crude mixed acetic and formic acids plus dissolved solids (oils, waxes, resins). These bottoms are passed through a heat exchanger into the flash drum *7* where the mixed acids and water are flash-vaporized from the dissolved solids. This flash stream is passed into the azeotropic column *8* against the entrainer, ethylene dichloride (EDC). In this column formic acid, water, and EDC distill overhead and are condensed into a decanter, *9*, where the formic acid and water separate from the solvent as two layers. The solvent layer returns to the column as reflux and the formic acid–water stream flows into column *10* against the same entrainer (EDC). The EDC-water azeotrope distills overhead from this column, is condensed, and passed to another decanter, *11*, where they separate into two layers. From the decanter, water goes to waste and the EDC is returned to the column as reflux. The bottoms from column *10* is 90% formic acid in water which is taken as vapor and condensed; it is then sent to storage as product.

The bottom stream from column *8* is glacial acetic acid containing traces of higher boiling organic acids and furfural. This is passed into the refining column *12* and glacial acetic acid is taken overhead as product. The bottoms from the flash drum *7* contains the resins and fats in a concentrated solution in mixed acetic and formic acids. This stream is passed into column *13* where the small amount of mixed acid is distilled overhead and is returned to the extractor feed, *5*. The resins and waxes are stored for further processing, now under development.

The raffinate liquor from extractor *5* is fed to a stripper column *14* where a small amount of the MEK-water binary is recovered and returned to the system for re-use. The solvent-stripped raffinate is fed to a forced-circulation evaporator co-effect *15* where it is concentrated to 50 to 55% solids, and is pumped to product storage. The concentrated raffinate is shipped to kraft mills in specially equipped tank cars.

PRODUCT SPECIFICATIONS AND BY-PRODUCTS

Table V gives the acetic acid specifications and Table VI the formic acid specifications to which the acids are manufactured. The raffinate as sold to kraft mills has the typical composition given in Table VII. The so-called resin and wax by-product mixture, designated as Product T-6B, is quite complex and its composition is not yet completely elucidated, though the work on it is still in progress. The materials so far identified qualitatively in this mixture are given in Table VIII. This material is commercially unique; it might be called the hardwood equivalent of tall oil;

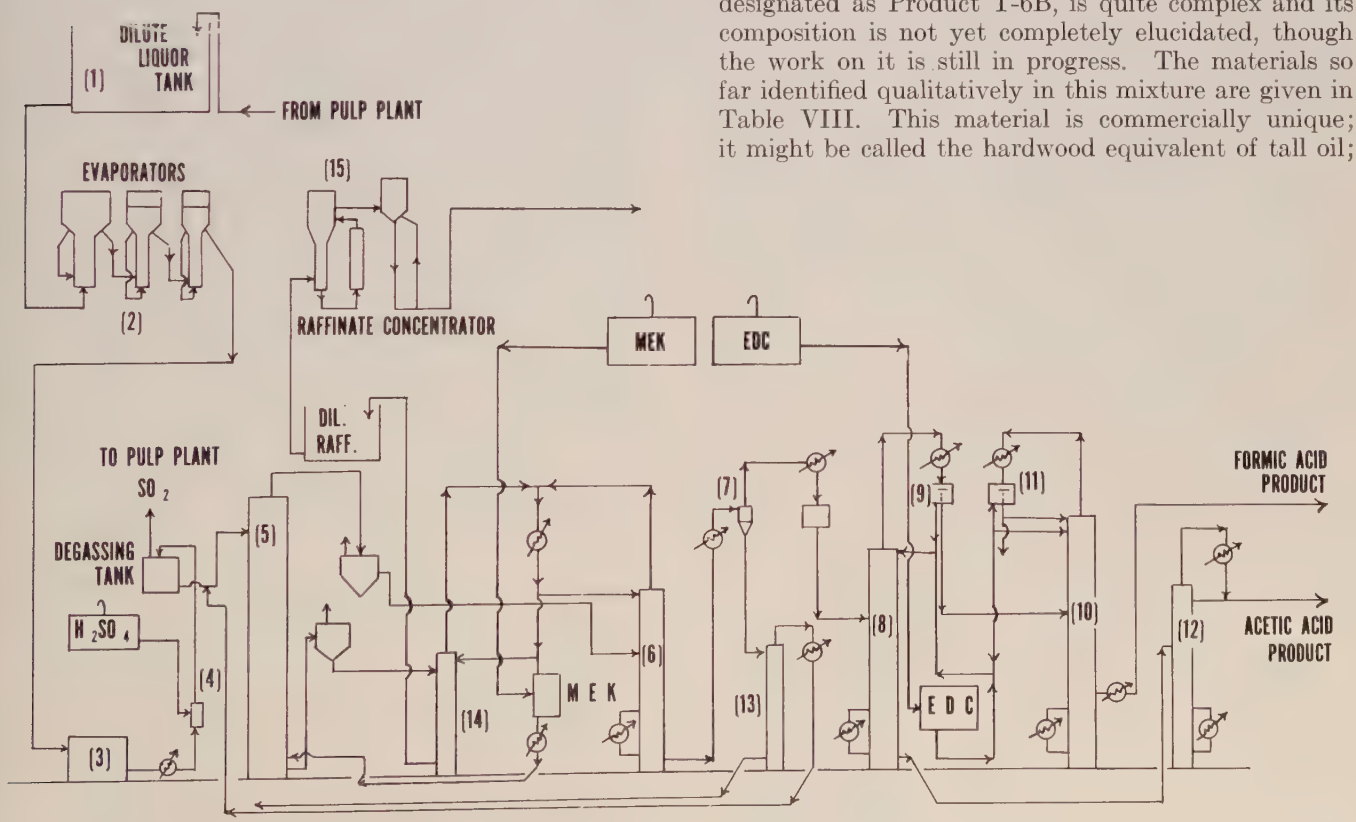

Fig. 5. Sonoco chemical recovery plant flowsheet

Table V. Sonoco Glacial Acetic Acid Specifications

Color	10 APHA max.
Freezing point	15.7°C. min.
Strength	99.5 wt. % min.
Formic acid	0.05 wt. % max.
Sp. gr.	1.048–1.053 @ 20°C.
Nonvolatiles	0.005 wt. % max.
Acetaldehyde	0.05 wt. % max.
Iron	1 p.p.m. max.

it is quite different, however, although they both contain fatty acids.

OPERATIONAL DIFFICULTIES

We began operations at Chemical Recovery in June, 1958. At once we had serious trouble due to an inability to pump the concentrated, acidified black liquor. This proved to be due to excessive SO_2 gas generation from the reaction of the sulfuric acid with residual sodium sulfite in the liquor. Adjustment at the pulp plant in cooking chemical concentration, etc., remedied this.

We then had serious extractor fouling by a gelatinous sludge composed mostly of very fine pulp and calcium sulfate which could not be screened out. Fortunately, we had evaluated several different types of extractors in pilot plant, and an alternative type was constructed. This has proved very satisfactory. The problem here was due to unforseen difficulty in scaling-up equipment size from pilot scale to full scale.

Before too long a most serious difficulty arose: corrosion. Neither our pilot plant nor previous experience in acetic acid manufacture by others anticipated this at all. The entire plant was constructed of stainless steel—some of it high-priced alloy. Nevertheless, we have replaced many pumps, pipes, instruments, and column internals. We now have this problem under control, although some components will shortly have to be replaced by ones made from alloys which our in-plant corrosion studies have proved to be satisfactory.

Another problem was calcium sulfate scale. This developed in such odd spots as centrifugal pump impellers, and is now under control though not entirely eliminated. Our most serious control problem was with maintaining water-white color in the acids, especially in the vapor phase. For these reasons we have not produced formic acid for sale as yet but we expect to be doing so very soon.

Mixtures of acetic and formic acids proved to be much more vicious corrosives than either alone, especially in association with higher molecular weight acids.

Evaporator scaling is considerable, but under control. This scale is mostly calcium oxalate and sulfate in an organic matrix.

ECONOMICS

The factors influencing the economics of organic acids recovery are myriad, as they are for any pulp mill chemical recovery process. Among these factors are the wood used, the amount and the concentration of black liquor solids available, steam and power costs, mill location, proximity to markets and raw materials sources, labor costs, etc. Of prime importance is the recovery of total dissolved solids with 90% or better efficiency at the pulp plant.

Table VI. Sonoco 90% Formic Acid Specifications

Color	5 APHA max.
Strength	90 wt. % min.
Acetic acid	0.5 wt. % max.
Sp. gr.	1.210 @ 60°F.
Nonvolatiles	0.010 wt. % max.
Chlorides	0.001 wt. % max.
Sulfates	0.004 wt. % max.

Table VII. Typical Analysis of Raffinate

Dissolved wood substance, %	50.0
Total sodium, as Na_2O, %	19.20
Total sulfur, %	11.05
Na_2SO_4 Equiv. (Na_2O Basis), %	44.0
Gross B. t. u., dry basis/lb.	4,000

The capital cost of a plant such as ours to process the black liquor from a 350 ton-per-day pulp mill is about 1.5 million dollars. If the pulp plant delivers 90% of the total solids produced, at the design rate, the plant will recover 90% of this as product per day, or about 40,000 lb. of glacial acetic acid, 5000 lb. of 90% formic acid, and 50 tons of salt cake equivalent, the latter being in 228 tons (40,000 gal.) of 50% solids processed black liquor.

The value of these products, before freight and sales costs, amounts to approximately $6000 per day. Total manufacturing costs before steam and power, but including depreciation, have proved to be approximately $2000 per day. Our steam and power costs amount to about $1000 per day. We have a margin then of $3000 per day to pay freight, sales and administrative expense, amortize the capital investment, and show a profit. Because of pulp washing difficulties, this efficiency of recovery has not been attained. Pulp plant equipment modifications, now being installed, should enable us to reach the 90% recovery goal.

Let us consider three mill situations bearing in mind the above factors.

1. An NSSC mill not integrated with kraft and using the Sonoco Process, but with no total recovery process for pulp chemicals.

This is our own situation. We are, however, within 200 miles of a textile industry consuming the greater part of the 25 million pounds of annual acetic acid shown in Table I, and about half of the 15 million pounds of formic acid shown in Table II. We are also within 50 to 130 miles of about 5000 daily tons of kraft production. Any nonintegrated NSSC mill must be in a somewhat relative position to utilize the Sonoco Process.

2. An NSSC mill with the Sonoco Process and a total recovery process for pulp chemicals.

This could be a good situation for organic acids recovery. In this case one would concentrate the

Table VIII. Materials Qualitatively Identified in Product T-6 B[a]

Syringic acid	Vanillic acid
p-Hydroxybenzoic acid	Succinic acid
Lactic acid	Oleic acid
Palmitic acid	Myristic acid
Lauric acid	Capric acid
C_{18} to C_{29} acids	Sterols
Vanillin	Acetovanillone
Syringaldehyde	Acetosyringone

[a] Resin and wax by-product.

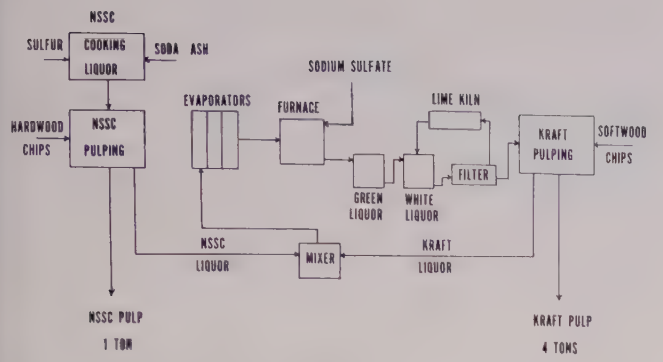

Fig. 6. Conventional integration of NSSC and kraft pulping

neutral black liquor, recover the organic acids, concentrate the raffinate, and burn it in a recovery furnace for sulfite chemical recovery by one of several applicable processes, such as the IPC, Mead, Western Precipitation, Sulfide Recycle, or Stora. In this way one would recover the sodium and sulfur value as sodium carbonate and sulfur dioxide, or sodium sulfite.

The recovered value of carbonate is considerably more than that of sodium sulfate on an equivalent sodium basis. The organic acids market situation would be a controlling factor. Another important factor would be the sulfur balance in the overall operation. The acidification of the NSSC liquor with sulfuric acid will add sulfur to the system in considerable excess of that used in the pulping process. This may be partially offset by inherent sulfur losses in the pulp and papermaking operation and recovery plant losses.

3. An NSSC mill integrated with kraft and organic acids recovery. This is an ideal situation for organic acids recovery for increased profit on the whole operation. Figure 6 shows how a conventional integration or cross-recovery is carried out, generally at a 1:4 ratio of NSSC-to-kraft. More NSSC pulping cannot be integrated into the chemical cross-recovery because of the adverse effect of more NSSC chemical on the kraft liquor sulfidity and the limiting chemical makeup requirements of the kraft operation. Consequently, most kraft mills now integrated with NSSC mills must still add salt cake and often additional sulfur as makeup to maintain their chemical balance and adequate sulfidity. This makeup chemical is not productive on the NSSC pulping side. The main reason for this is that when NSSC liquor is smelted, the bulk of the sodium reduces to sodium carbonate rather than sodium sulfide.

Now, when NSSC black liquor is acidified with sulfuric acid, all the organic acid salts yield the organic

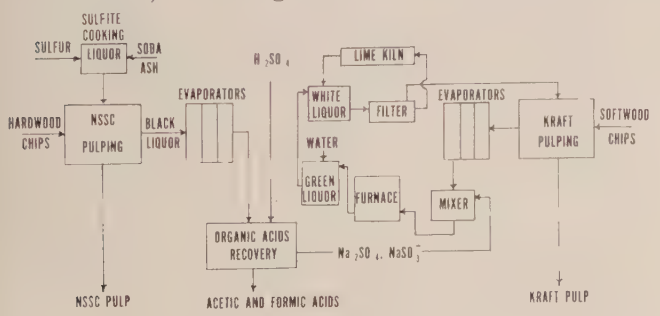

Fig. 7. Total integration of NSSC and kraft pulping with acetic and formic acids recovery

Table IX. Comparative Data for Typical Integration With and Without Organic Acids Recovery

	NSSC	*Kraft*	*Integrated — No acid recovery*	*Integrated — With acid recovery*
Total alkali as Na_2O/ton total pulp, lb.	146	108	86.4	62
Acetic acid/ton sulfite, lb.	0	0	0	100
Formic acid/ton sulfite, lb.	0	0	0	12
Tons sulfite/ton kraft	...	...	0.25	0.74

acids plus sodium sulfate. Only the sodium sulfonated lignin appears to remain unconverted. This means that all the nonsulfur-combined sodium in the NSSC liquor is converted to the sulfur-combined form. When this acid liquor is smelted all the inorganic is reduced to sodium sulfide at the particular furnace efficiency, except the sulfonic acid salts, although some sodium carbonate will be formed due to reaction of CO_2 with the sulfide. Theoretically, two moles of $NaSO^-_3$ will yield one mole of sodium sulfide and one mole of sulfur dioxide. The sulfur dioxide should, for the most part, react in the smelt to yield more sulfide. This increment of sulfur is an excess over that provided by salt cake makeup. The net result of all this is that the sulfuric acid acidified NSSC liquor can be used as the entire kraft makeup chemical and NSSC pulping can be practiced in integration up to the extent of the entire kraft makeup.

In order to achieve this desirable result, however, the acetic and formic acids must be removed from the acidified NSSC liquor before mixing for recovery with kraft liquor. If sulfuric acid acidified NSSC liquor, still containing these organic acids, is mixed with the highly alkaline kraft liquor, they react with the alkali to re-form their sodium salts, generating hydrogen sulfide. Hence, the equivalent alkali will smelt to sodium carbonate and the hydrogen sulfide will burn to sulfur dioxide and be largely lost up the stack. This is a worse situation than smelting the neutral NSSC liquor.

If, however, the organic acids are removed from the acidified NSSC liquor before smelting with kraft liquor, these reactions cannot occur and all the sodium will remain combined with the sulfur within the capability of the furnace.

Figure 7 illustrates a typical example of such an integration and Table IX gives the material balance whereby one is able to pulp NSSC and kraft at a ratio as high as 0.75:1 while maintaining a high kraft liquor sulfidity. The pulping ratio for individual situations will be different, but in any event much more NSSC can be integrated with kraft than is now

Table X. Production of Major Acetic Acid–Consuming Chemicals (*10*)

	Millions of pounds		
	1957	*1958*	*1959*
Cellulose acetate	450	477	538
Vinyl acetate	172	190	244
Ethyl acetate	92	86	101
Butyl acetates	72	85	92
Monochloroacetic acid	47	38	43
Aspirin	18	21	18
Acetic acid salts	17	15	20
Methyl acetate	8	6	9
Amyl acetate	...	9	10
Isopropyl acetate	...	...	31

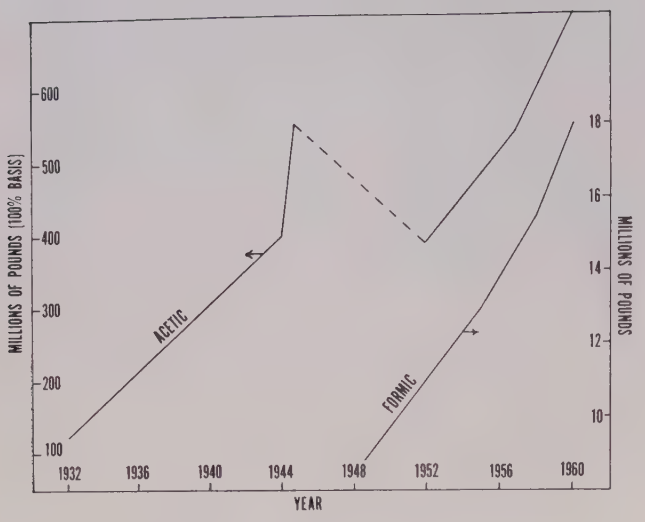

Fig. 8. Growth of acids market

the case, except in those processes where fractional crystallization of sodium carbonate from the green liquor is practiced. This practice can, of course, be followed in the example cited here for further advantage, if desired.

The net result of this new integration is that one can produce more total pulp per pound of sodium oxide used, put in sulfuric acid at about \$0.01 per pound and recover its equivalence as acetic acid for sale at \$0.10 per pound and formic acid at \$0.15 per pound.

The Future Promise for NSSC Black Liquor Organic Acids Production

The demand for acetic acid and formic acid is growing (*8, 9*). Figure 8 shows the growth of these markets. Table X shows the growth in production of some important acetic acid uses. Figure 9 shows the price trends of acetic and formic acids and the necessary sulfuric acid (*11*).

The petrochemicals industry can produce glacial acetic acid from ethylene and propylene at a cost estimated to be as low as \$0.05 per pound. It should

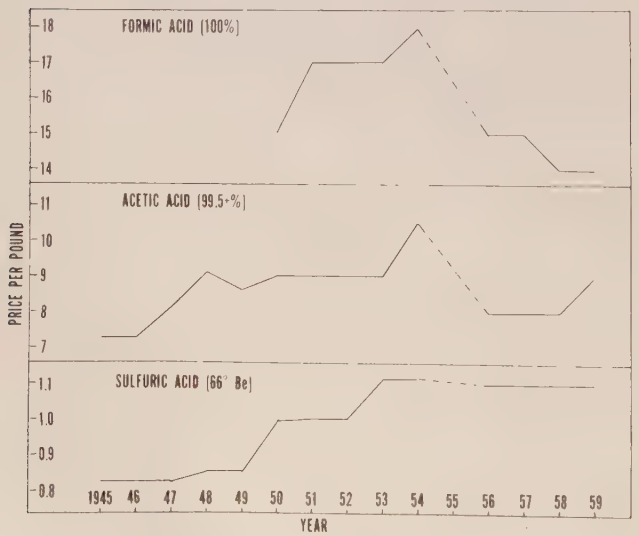

Fig. 9. Price trends

be more profitable for them to divert the equivalent amount of gas, however, into polyethylene, polypropylene, and polyvinyl acetate, etc.

Large NSSC integrated operations, particularly with kraft pulping, should produce very serious competition to petrochemical acid, especially since the acid would be produced as a by-product of paper manufacture rather than as a prime product.

In the case of formic acid, more uses must be developed for it to expand the market very much.

PATENTS AND LICENSING

The Sonoco Recovery Process for acetic and formic acids is covered by U. S. patents 2,714,118, issued July 26, 1955, 2,744,927, issued May 8, 1956, and 2,974,081, issued March 7, 1961. The latter covers the basic process improvement of NSSC-kraft cross-recovery or integration whereby the NSSC liquor is acidified with sulfuric acid to liberate acetic and formic acids, the acids are removed from the acidified liquor, and the resulting acid-stripped liquor is smelted with kraft liquor to obtain the benefits just disclosed.

The licensing and engineering rights to the Sonoco Process are under consideration.

CONCLUSIONS

1. With the experience gained in the design and operation of the first installation of the Sonoco recovery process at Hartsville, it is possible to build and operate a recovery system of this type successfully to dispose of the NSSC black liquor stream pollution problem.

2. The economic justification for such a plant, where not integrated with total chemical recovery or with kraft production, is doubtful except for very special situations dictated by economic geography such as the Sonoco case.

3. It is possible that by-product values may develop from the process which may alter the present unintegrated restrictions.

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It required a great deal of imagination, courage, and faith for the management of Sonoco to support this pioneering research and development effort and to finally take the plunge to invest so much in the construction of this plant and all the supporting auxiliaries required. By present-day corporate standards, Sonoco is not a very large company. Again, although we have manufactured certain chemicals for our own use for years, we are neophytes in the competitive chemical industry.

We wish to acknowledge particularly the unswerving support of our former president, the late J. L. Coker, C. W. Coker, president, R. G. Coker, vice-president for engineering, and J. H. Martin, vice-president for production.

Mill Experience with the Elvasize Process

B. A. BEARDWOOD and C. J. STAPF, JR.

The Elvasize process is a method for surface-sizing paper and paperboard with Elvanol polyvinyl alcohol. The process is a two-stage sizing technique—a borax solution pretreatment followed by a polyvinyl alcohol size. The borax reacts chemically with polyvinyl alcohol, cross-linking the polymer to form a firm gel. This reaction, which occurs at the surface of the sheet, prevents excessive penetration of the polyvinyl alcohol size. This sizing technique provides excellent holdout of oils, greases, solvents, waxes, and pigmented coatings and improves the strength and abrasion resistance of the sheet. The polyvinyl alcohol size solution of the two-stage process can be extended with starch, which is beneficial for certain applications. For sizing alkaline paper and paperboard, a one-stage version of the Elvasize process has been developed. In this system the polyvinyl alcohol size solution is modified with boric acid. When the modified size solution is applied to the alkaline sheet, the boric acid is converted to the borate form which then reacts with polyvinyl alcohol. The borax solution can be applied by size press, on-machine coater, calender stack, or spray. The polyvinyl alcohol, or polyvinyl alcohol–boric acid size can be applied by size press, on- or off-machine coaters, or calender stack. Commercial mill use of the Elvasize process has resulted in surface sizing costs lower than those of most other surface sizing methods.

A NEW process for surface sizing paper and paperboard with Elvanol* polyvinyl alcohol, the Elvasize process, was introduced to the paper industry recently (*1*). It is now in commercial use at eight mills. Such rapid progress and the great interest shown at other mills where trials have been run are due to the ability of the Elvasize process to combine higher quality surface sizing with lower sizing costs.

Polyvinyl alcohol, a water-soluble polymer, demonstrates several important properties when applied as a film or coating. Polyvinyl alcohol films are clear, tough, and flexible. They are resistant to greases, oils, and solvents, and also are highly impermeable to most gases. Because of this unusual combination of properties in a single material, polyvinyl alcohol has been used for many years as a size and as a clear coating for paper and paperboard. In specific applications, the use of polyvinyl alcohol proved highly successful and continues to be used today. In other cases, however, polyvinyl alcohol has been uneconomical as a size and clear coating because too much of it penetrated into the sheet, necessitating the application of excessive amounts of polyvinyl alcohol in order to have a layer of the polymer on the surface of the sheet.

The Elvasize process, which controls the penetration of polyvinyl alcohol solutions into paper and paperboard, was developed in 1960. This method employs a pretreatment of borax solution, followed by a polyvinyl alcohol size. As described earlier (*2*), borax reacts instantaneously with polyvinyl alcohol to form a didiol complex (Fig. 1).

The formation of the didiol complex of borax and polyvinyl alcohol results in the development of a stable three-dimensional gel structure. This reaction takes place instantaneously on the surface of the sheet and prevents the polyvinyl alcohol size from penetrating.

The effect of a borax pretreatment in controlling penetration of a polyvinyl alcohol size is shown in Figs. 2a and 2b. The photomicrographs show cross sections of two samples of solid, bleached sulfate paperboard. The sample of board in Fig. 2b was coated with a 4% solution of Elvanol 72-60 polyvinyl alcohol; the board in Fig. 2a was treated with the Elvasize process, using a pretreatment of 5% borax solution and a coating of 4% Elvanol 72-60. In both cases the polyvinyl alcohol

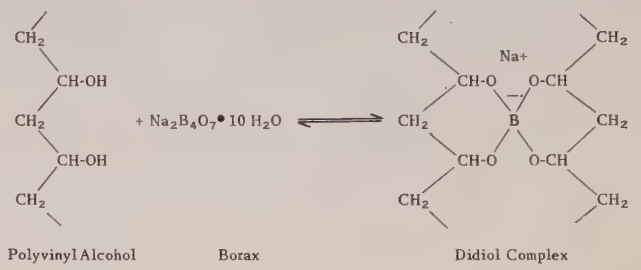

Fig. 1

solutions were colored with a blue dye for easy indentification under the microscope.

In Fig. 2b the polyvinyl alcohol can be seen as a dark band below the surface, indicating that part of the polyvinyl alcohol has been wasted. Fig. 2a shows how the Elvasize process prevents this penetration, maintaining all of the size on the surface of the sheet.

Since the Elvasize process was first introduced, a great deal of mill experience has been obtained with this new technique for surface sizing with polyvinyl alcohol. Although the principal application of the Elvasize process has been sizing of paperboard for high gloss printing, many other applications are being studied. These other applications for the Elvasize process on paperboard include improving grease, oil, and solvent resistance; as a general holdout size for pigments and clear coatings; as a gas barrier coating; and improving strength and abrasion resistance. Other studies currently under way include the utilization of the process for improved wax holdout on breadwrap, and improving the erasability and strength of bond writing papers.

A modified version of the process has been used in mills to size alkaline paper and paperboard. On an alkaline surface, results comparable to those obtained in the Elvasize process can be achieved with a single application of a polyvinyl alcohol–boric acid mixture. Under acidic conditions, mixtures of polyvinyl alcohol and borax are compatible; but when applied to an alkaline

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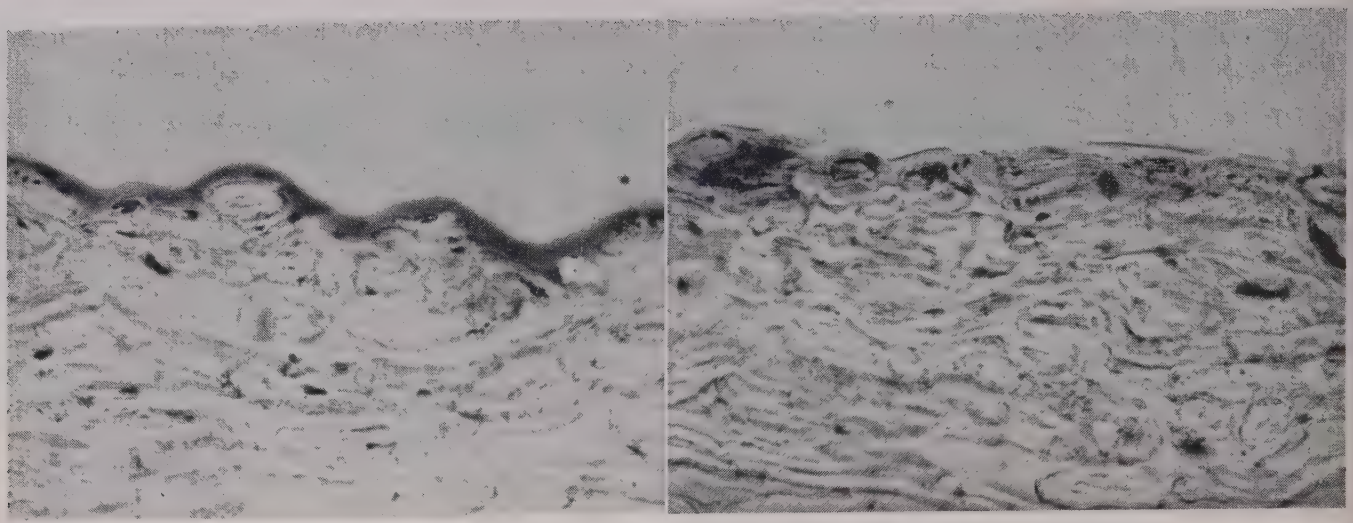
* Elvanol is du Pont's registered trademark for its polyvinyl alcohol.



ELVASIZE PROCESS

REGULAR SIZING TECHNIQUE

Figs. 2a and 2b. The effect of borax pretreatment on penetration of a polyvinyl alcohol size

Fig. 2a (left). The photomicrograph shows the controlled penetration available with the Elvasize process. The dark layer on the surface of the paperboard is polyvinyl alcohol size.

Fig. 2b (right). The dark band below the surface of the paperboard shows how the polyvinyl alcohol size penetrates into the board when regular sizing techniques are used.

sheet, the boric acid is converted to the borate form and gels the polyvinyl alcohol.

Some work has been done with mixtures of polyvinyl alcohol and starch solution with the Elvasize process. Mill experience has shown that in some applications excellent sizing results can be obtained with starch-extended polyvinyl alcohol sizes.

This paper summarizes much of the experience which has been achieved with the Elvasize process in the mill. The data and information reported are based on actual mill experience with the process in more than 20 different paper mills. Many other mill evaluations of the process have been made, and the data from these runs further support the information disclosed.

THE ELVASIZE PROCESS IN THE MILL

The Elvasize process is currently in commercial use at a number of mills. Owing to the nature of the process, a two-stage system, initial adoption has been made most readily in mills producing paperboard. The availability of water boxes on the calender stacks of paperboard machines facilitates the application of two solutions. Generally, size applications are not made on the calender stacks of paper machines. In most cases there is usually only a single size press available on a paper machine, which can accommodate only the borax solution or the polyvinyl alcohol size. Work is underway, however, to devise alternate methods for applying the borax pretreatment. Success in this endeavor will widen the application possibilities for the Elvasize process in the paper industry.

In the paperboard industry, where the process can usually be applied on existing board machine equipment, its commercial adoption so far has been primarily for surface sizing for high-gloss printing. Ease of application, sizing versatility, high sizing quality, and lower surface sizing costs account for acceptance of the Elvasize process.

SURFACE SIZING FOR HIGH-GLOSS PRINTING

The many trials with the Elvasize process on various types of paperboard have demonstrated the wide range of oil resistance which can be obtained on paperboard by changing the concentration of either the borax pretreating solution or the polyvinyl alcohol size. Using the standard Vanceometer absorption technique (*3*) and standard viscosity oil NCS-12† to measure oil resistance, the sizing versatility of the process can be demonstrated by data from two mills.

In the first mill a rather dense, solid bleached board was sized in two runs with a 2% solids solution of Elvanol 72-60, a fully hydrolyzed, high-molecular-weight grade of polyvinyl alcohol. The first run employed a pretreatment with a 2% solids solution of borax (sodium tetraborate decahydrate), while the second run used a 5% solids solution of borax. The effect of borax concentration on oil absorption can be clearly seen by comparing the Vanceometer data in Fig. 3. By increasing the borax concentration it is possible to maintain more of the polyvinyl alcohol on the surface of the board, which results in greater oil resistance. In work with the Elvasize process, generally a 5% borax solution is best for commercial operation; but this will differ in some cases. Factors which affect borax concentration are discussed later.

Vanceometer results from a second trial show the effect of polyvinyl alcohol concentration on oil absorption. The Vanceometer data in Fig. 4 were obtained on another grade of solid bleached board which had been sized with the Elvasize process, starch, and straight polyvinyl alcohol. The effect of a pretreatment with 5% borax solution can be seen by comparing run 2 (2.3% Elvanol 72-60) with run 3 (5% borax-2.3% Elvanol 72-60). As the concentration of the polyvinyl alcohol size is increased, the degree of oil resistance is increased. Under the sizing conditions of a 5% borax solution pretreatment and a 5% solids polyvinyl alcohol size, complete oil holdout was achieved for longer than the 70-sec. test period.

Commercial Performance and Costs

Although complete oil resistance is desirable in many applications, generally in sizing for high-gloss printing a

† NCS-12 oil, Hillside Laboratory, Chicago, Ill.

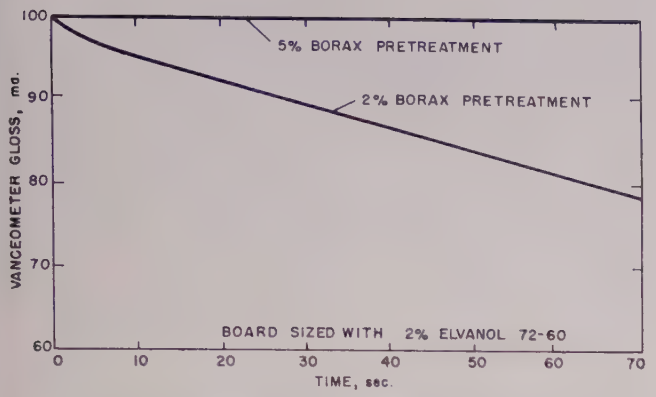


Fig. 3. Effect of borax concentration on oil absorption of board sized with the Elvasize process

small degree of oil penetration is needed. In order to prevent offsetting of a printed image onto the back of printed sheets, some ink penetration is required to set or dry the ink.

A commercial run on patent-coated newsboard in one mill compared the cost and performance of the Elvasize process with the regular starch-alginate size. In this evaluation the Elvasize process consisted of a pretreatment of 5% borax solution and a size of 3% Elvanol 72-60. Both the regular size and the Elvasize process were applied at the calender stacks of the board machine. The Vanceometer data presented in Fig. 5 show that the Elvasize process provided a higher degree of oil resistance. In addition to the better performance obtained, the mill reported a reduction of over 50% in surface sizing costs with the borax–polyvinyl alcohol technique. The board sized with polyvinyl alcohol was

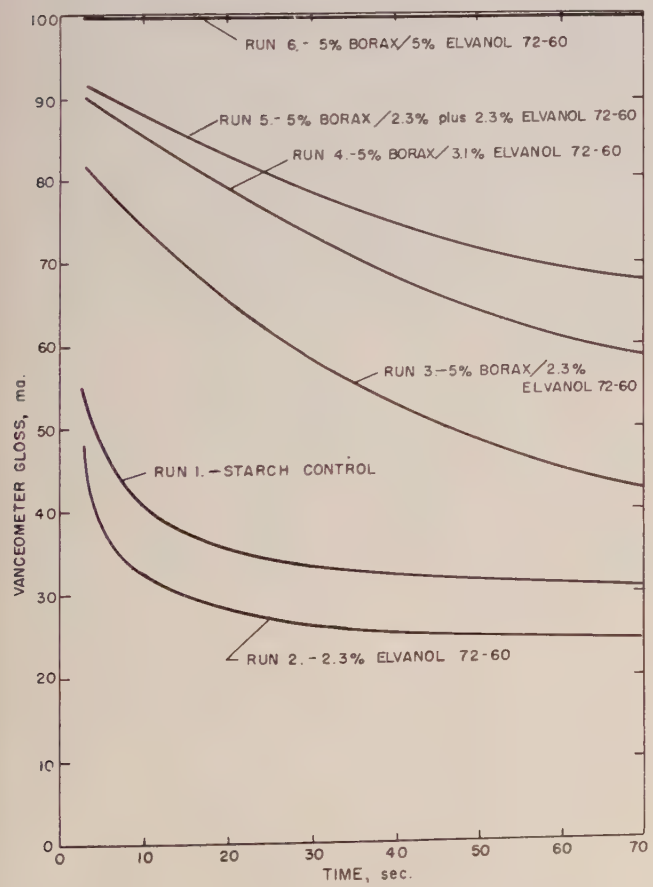

RUN 6.- 5% BORAX/5% ELVANOL 72-60
RUN 5.- 5% BORAX/2.3% plus 2.3% ELVANOL 72-60
RUN 4.-5% BORAX/3.1% ELVANOL 72-60
RUN 3.-5% BORAX/2.3% ELVANOL 72-60
RUN 1.-STARCH CONTROL
RUN 2.-2.3% ELVANOL 72-60
VANCEOMETER GLOSS, ma.
TIME, sec.

Fig. 4. Effect of polyvinyl alcohol concentration on oil absorption of board sized with the Elvasize process

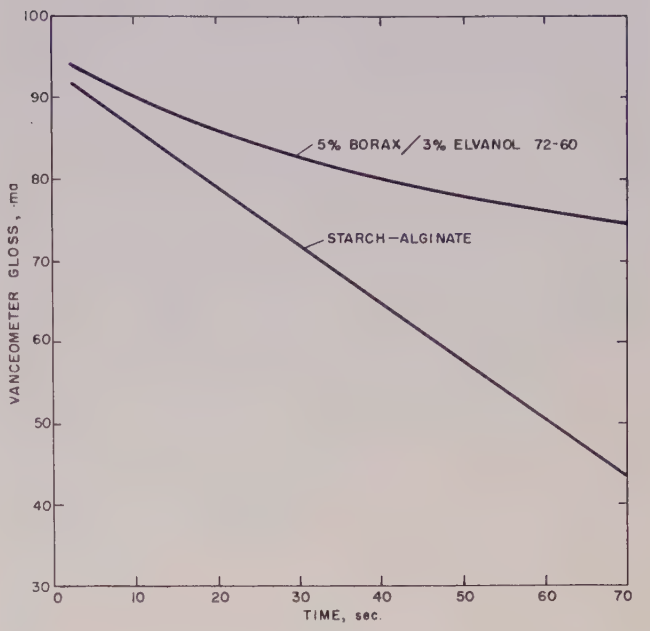


Fig. 5. Oil absorption of patent-coated newsboard sized commercially with the Elvasize process

one point brighter than the board with the regular size. This is probably due to the fact that only one-quarter of the normal size solids were applied to the board, and that the polyvinyl alcohol film is much more transparent than the normal starch film.

In a second mill, patent-coated newsboard was sized commercially with the Elvasize process and the regular system, consisting of a starch-alginate combination. A 5% borax solution and 3% Elvanol 72-60 size were applied. For comparison a straight 3% Elvanol 72-60

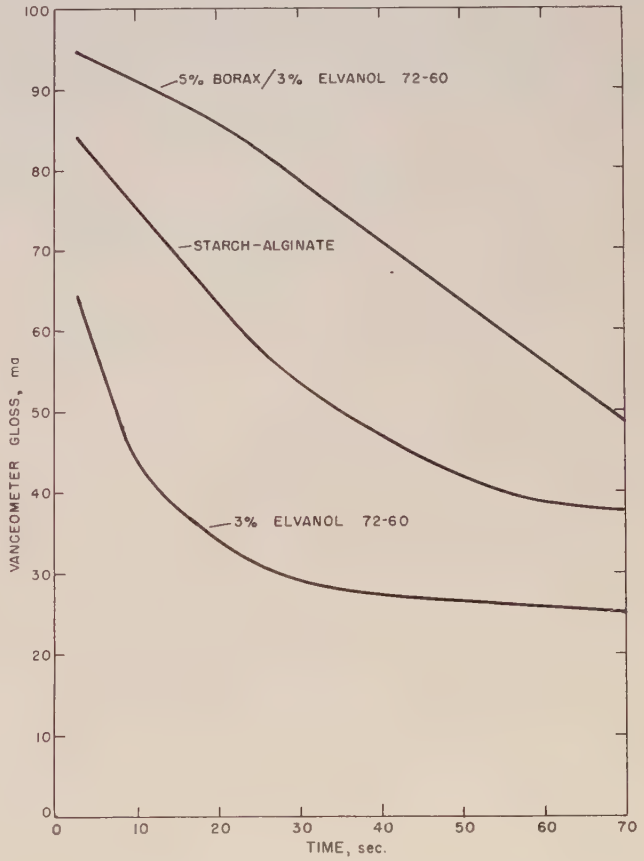


Fig. 6. Oil absorption of patent-coated newsboard sized commercially with the Elvasize process

size was applied in a third run. The Vanceometer data in Fig. 6 show the advantage in oil resistance with the Elvasize process. As was the case in the other-patent coated newsboard trial, surface sizing costs were reported to be about 50% lower with this process.

In some mills which produce board with high-gloss printing and flat printing properties, it has been found convenient to switch from high gloss to flat by simply removing the borax pretreatment. This possibility is shown in Fig. 6.

Other mills producing paperboard with other surface sizing requirements have also reported that the Elva-

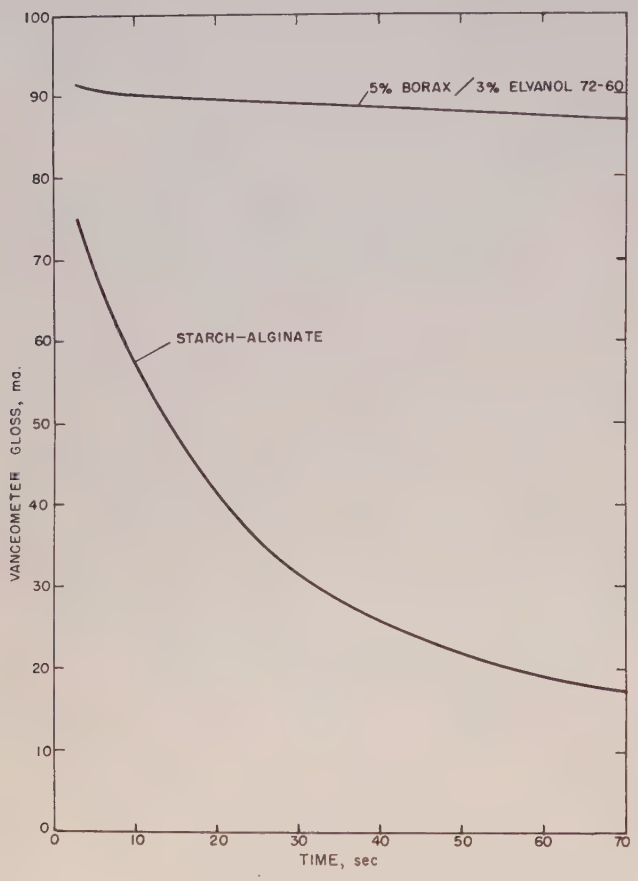


Fig. 7. Oil absorption of bleached manila lined board sized commercially with the Elvasize process

size process offers cost savings. Surface sizing costs as low as \$0.50–0.60 per ton have been reported with 3% borax solutions and Elvanol 72-60 at concentrations ranging from 1.0 to 1.5% solids.

Commercial runs with the Elvasize process have been made successfully for high-gloss printing on other types of paperboard, including bleached manila lined board. In one mill evaluation on bleached manila lined board, the Elvasize process was compared again with a starch-alginate size. As was the case before, the Elvasize process consisted of a pretreatment with 5% borax solution and a size with 3% Elvanol 72-60 polyvinyl alcohol. Although no cost data were reported, the Vanceometer oil absorption data, plotted in Fig. 7, show that the borax–polyvinyl alcohol method gave superior oil resistance.

It was noted in this evaluation on bleached manila lined board that a brightness drop of about one point

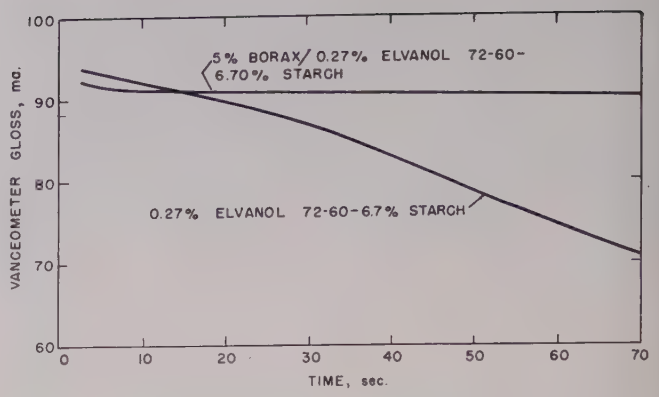


Fig. 8. Oil absorption of patent-coated newsboard sized commercially with the Elvasize process (starch modification)

was experienced on the board treated with the Elvasize process. Slight brightness losses have also been noted on other grades of paperboard which contain groundwood pulp. This brightness drop on groundwood pulps, which is due to the alkalinity of the borax pretreatment, is discussed in detail below.

Extenders for Polyvinyl Alcohol Size

It is well known that polyvinyl alcohol solutions are very compatible with many grades of starch, as well as many other materials which are used in the paper industry. It has been demonstrated that solution mixtures of polyvinyl alcohol and starch can be used with the Elvasize process. When applied to a borax-treated sheet, polyvinyl alcohol, even in the presence of starch, reacts with the borax and forms a stable gel structure. The gelled polyvinyl alcohol physically blocks starch penetration, keeping both materials on the surface of the sheet.

Obviously, the ratio of polyvinyl alcohol to starch in the size mixture, the total concentration of the size solution, and the concentration of the borax pretreatment all affect the amount of size which will remain on the surface of the sheet. In applications where a starch size is modified with small amounts of polyvinyl alcohol and applied over borax, the polyvinyl alcohol in conjunction with the borax acts as an agent for size penetration control.

Although some mills are using polyvinyl alcohol–starch combinations with the Elvasize process, no comprehensive study has been made with this combination. General practice in the mill has been to start with one part polyvinyl alcohol and one part starch. The ratio of starch-to-polyvinyl alcohol is then increased as long as the desired properties of the sized sheet are maintained. Using this approach, some mills are successfully using the Elvasize process with a size consisting of 6–8 parts starch and 1 part polyvinyl alcohol at a total concentration of 3 to 4% solids. In mills with certain surface sizing requirements, use of starch-polyvinyl alcohol combinations with a borax pretreatment has proved to be beneficial from both a quality and cost standpoint.

A mill evaluation was made on patent-coated newsboard with the Elvasize process, using a high ratio of starch-to-polyvinyl alcohol. Two runs were made using size solution consisting of 6.70% starch and 0.27% Elvanol 72-60. In one run a 5% borax solution

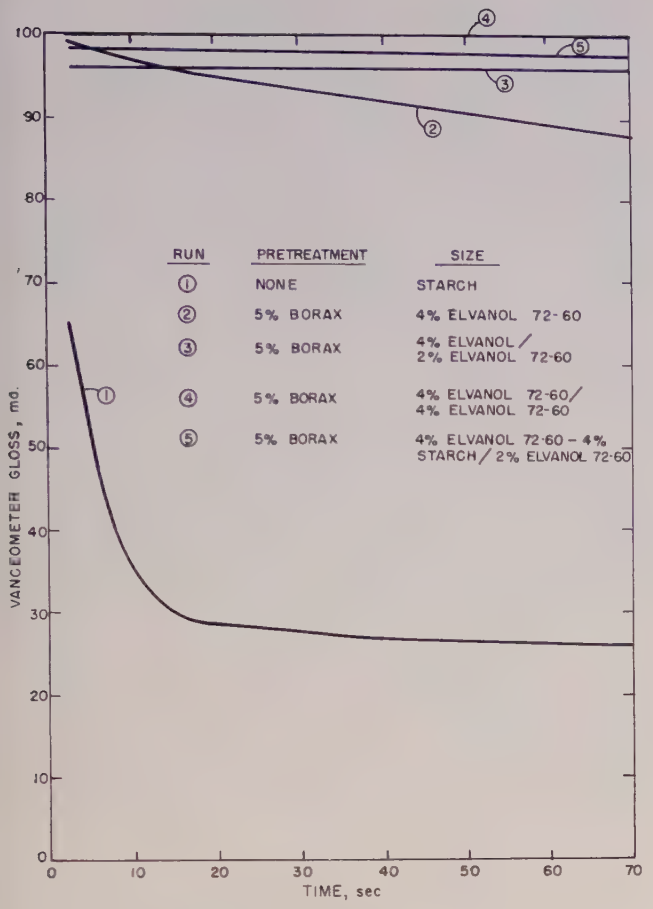


Fig. 9. Oil absorption of bleached manila lined board sized with the Elvasize process

was used as a pretreatment; in the other no pretreatment was used. Samples of the board from both runs were tested for oil resistance; the Vanceometer data are plotted in Fig. 8. These data show that, in spite of the low level of polyvinyl alcohol present in the size, the borax–polyvinyl alcohol gelling reaction was helpful in maintaining more of the size on the surface of the sheet, resulting in greater oil resistance on the surface of the board. The board was also tested for resistance to SAE-50 oil. Time for 50% penetration‡ of this oil was measured on the Vanceometer and found to be four times greater on the board sized with the Elvasize process.

SURFACE SIZING FOR GREASE AND OIL RESISTANCE

Success in producing a greaseproof or oilproof paper or paperboard depends upon the ability to apply a continuous layer or film of a greaseproof material. The Elvasize process helps in this respect by maintaining most of a polyvinyl alcohol size on the surface of the sheet. The problem, however, is to apply enough size to prevent pinholing, or to apply multiple layers of size to cover pinholes. This is an extremely difficult task to accomplish on a paper machine.

Current efforts with the Elvasize process have been directed to producing paperboard with improved grease and oil resistance. As the formation of a continuous film of polyvinyl alcohol on paperboard is approached, the degree of grease and oil resistance is improved.

An interesting mill evaluation was made on a bleached manila lined board with the Elvasize process for grease and oil resistance. The trial consisted of five runs. Board was sized with the regular starch size as a control in one run. The other four runs were made with the Elvasize process, using a pretreatment of 5% borax and size based on Elvanol 72-60.

Board from the several trials was conditioned (TAPPI Standard T 403 M-58) and then tested for Vanceometer oil absorption, turpentine resistance (TAPPI Standard T 454 M-44), and oil resistance. Oil resistance was measured by noting the time required for 50% penetration of two oils. The oils used were standard viscosity mineral oil NCS-12 and SAE-50 oil.

The five runs and the test data are summarized in Table I. Where 50% oil penetration did not occur in 24 hr. the Vanceometer gloss is reported after 24 hr. Vanceometer oil absorption data are plotted in Fig. 9.

Turpentine resistance of more than 300 sec. was achieved on board sized in two runs with the Elvasize process. Double water box application of 4% Elvanol 72-60 solution over a borax pretreatment and applications of 4% Elvanol 72-60/4% starch combination and 2% Elvanol 72-60 over a borax pretreatment gave the best improvement in grease and oil resistance. At the present time, medium and low viscosity grades of fully hydrolyzed polyvinyl alcohol are also being tested for this application. Use of these grades allows the preparation of more highly concentrated solutions of polyvinyl alcohol.

SURFACE SIZING FOR OTHER APPLICATIONS

Although complete mill data are not available on the performance of the Elvasize process in other applications, many preliminary mill trials have been made investigating new uses for the process. Initial mill reports have indicated several potential areas of application for the process.

The possible applications fall into two categories. One is where a barrier size of polyvinyl alcohol is applied to a sheet. Commercial examples of this are the use of the process for high-gloss printing and for oil resistance. Mill trials have been made employing the polyvinyl alcohol size as a barrier to wax, solvent, lacquer, varnish, expensive release coatings, and water-based coatings. Another possible application for the polyvinyl alcohol

‡ Vanceometer gloss at 50% penetration = $\frac{\text{base stock gloss} + 100}{2}$.

Table I. Grease and Oil Resistance of Bleached Manila Lined Board

	Pretreatment, Top water box, Run first wet stack	*Size* — *Bottom water box, first wet stack*	*Water box, second wet stack*	*Turpentine Resistance, sec.*	*50% oil penetration, sec.* — *NCS-12*	*SAE-50*
1	None	Regular starch	Water	7	0.5	110
2	5% borax	4% Elvanol 72-60	Water	23	243	10,700
3	5% borax	4% Elvanol 72-60	2% Elvanol 72-60	44	3750	98[a]
4	5% borax	4% Elvanol 72-60	4% Elvanol 72-60	366	6210	100[a]
5	5% borax	4% Elvanol 72-60 4% Starch	2% Elvanol 72-60	310	5730	100[a]

[a] Where 50% oil penetration did not occur in 24 hr., Vanceometer gloss was reported after 24 hr.

barrier size would be for improving the impermeability of paper, or paperboard, to air and many gases. Only water vapor and ammonia permeate polyvinyl alcohol films to any significant degree.

Another use suggested for the Elvasize process is in controlling the penetration of various coating formulations. A commercial example of this use is the application of polyvinyl alcohol–starch sizes over a borax pretreatment. In this case the polyvinyl alcohol in conjunction with the borax acts as a penetration control agent. This approach can be used with essentially any material which tolerates a small modification with polyvinyl alcohol. For example, release agents or resin emulsions could be modified with 1 to 5% polyvinyl alcohol and the combination applied to a borax-pretreated surface. The gelling reaction between the borax and the polyvinyl alcohol would prevent excessive penetration of the coating formulation. Because all grades of polyvinyl alcohol, including the fully and partially hydrolyzed types, react with borax in the same manner, there is a wide choice of polyvinyl alcohols for this purpose. This would allow use of the proper grade of polyvinyl alcohol in formulating for improved stability and viscosity control of the coating formulation.

APPLICATION INFORMATION

The Elvasize process is a two-stage sizing technique involving the application of two incompatible chemical solutions to paper and paperboard. So that the system may operate satisfactorily a solution of borax must first be applied to the sheet, followed by the application of a polyvinyl alcohol size solution. This allows the gelling reaction to take place on the surface of the sheet. Care should be taken to ensure against inadvertent mixing of borax and polyvinyl alcohol solutions whether it be in mixing tanks, pipes, on the machine, or in the sewer.

The reaction between borax and polyvinyl alcohol to form the didiol complex is pH-reversible. In an acidic system the borax is converted to boric acid. Boric acid and polyvinyl alcohol solutions are compatible, remaining fluid in a wide range of concentrations. It is possible therefore to prevent, or reverse, the gelling reaction between borax and polyvinyl alcohol by the addition of acids to the polyvinyl alcohol size.

Chemicals containing 1, 2- or 1, 3-diol groups also react with borax similarly to polyvinyl alcohol. For example, sorbitol and mannitol react with borax. In a system containing polyvinyl alcohol, sorbitol, and borax, the reaction between borax and sorbitol occurs preferentially. Cross-linking of the relatively short hexanehexol (i.e., sorbitol and mannitol) chains does not cause gelation of the system at low solids concentrations. For this reason sorbitol is effective in preventing the borax–polyvinyl alcohol gel.

It is important to remember that the success of the Elvasize process depends upon the borax–polyvinyl alcohol reaction. If significant amounts of acids or sorbitol are present in the polyvinyl alcohol size, the effectiveness of the Elvasize system is lost.

Borax Application

In the practical application of the Elvasize process on paper, or paperboard, it is only that borax which is on or near the surface of the sheet which reacts with the polyvinyl alcohol. Because the pretreatment solution of borax penetrates the sheet to some degree, it is necessary to apply more borax than is theoretically required in order to have sufficient borax available on the surface. Therefore, depending upon the water resistance, density, and moisture content of the sheet, different levels of borax pretreatment will be required to give maximum polyvinyl alcohol holdout. Likewise, depending upon the method of borax solution application, various concentrations of borax solution should be employed.

A 5% solids solution of 10 MOL borax ($Na_2B_4O_7.10H_2O$) is usually a sufficiently high concentration to ensure maximum polyvinyl alcohol holdout. In many applications, however, borax concentration of 3 to 4% has been adequate. It is desirable to determine the optimum borax concentration for three reasons: (1) to provide minimum cost, (2) to maintain maximum polyvinyl alcohol holdout, and (3) to minimize any potential effect of borax on other sheet properties.

In the application of the Elvasize process for high-gloss printability on patent-coated newsboard, optimum borax addition has been in the range of 0.06 to 0.25 lb. per 1000 sq. ft. (1.2 to 5.0 lb. per ton). 5 MOL borax ($Na_2B_4O_7.5H_2O$) can be used equally well with the Elvasize process. When substituting 5 MOL for 10 MOL borax, about 25% less borax is needed for equivalent results.

Borax pretreatments have been applied in a number of different ways on paperboard machines. Where two or more calender stacks on a board machine are equipped with water boxes, the borax solution has generally been applied on the first stack. Where only one stack is available, and it will be used for the polyvinyl alcohol size, it is necessary to apply the borax at another station. For this purpose a size press or coater has been used. Other possibilities would be to apply the borax at a breaker stack or from a simple applicator roll installed at a convenient position. Work is under way at present, however, to develop a system for controlled and uniform spraying of borax solutions.

Polyvinyl Alcohol Size Application

After pretreating the board with enough borax to give maximum polyvinyl alcohol holdout, the minimum level of polyvinyl alcohol addition is determined for the degree of oil resistance required. With any one method of size application, polyvinyl alcohol addition is usually controlled by changing the size concentration.

For high-gloss printability on paperboard polyvinyl alcohol solutions with concentrations in the range of 1 to 4% solids have been used. Application weights of polyvinyl alcohol have been in the range of 0.03 to 0.15 lb. per 1000 sq. ft. (0.6 to 3.0 lb. per ton).

When using polyvinyl alcohol or polyvinyl alcohol-starch sizes with the Elvasize process it is desirable to maintain the viscosity of the size at a minimum. This will aid in fluid-handling operations. Whereas high viscosities aid in size holdout in regular sizing techniques, the gelling effect of borax overshadows the effect of the initial viscosity of the size.

* Notation used by U. S. Borax Co. giving number of molecules of water of crystallization of borax.

In most commercial applications of the Elvasize process no problems have been encountered with borax leaching and contaminating the polyvinyl alcohol size reservoir. This is particularly true when the borax pretreatment is maintained at an optimum level. In some cases, however, it has been noted that a minor viscosity buildup occurs in the recirculated polyvinyl alcohol size. This viscosity buildup is generally a slow process, occuring over a period of hours. In the mills where viscosity buildup has taken place, it has been possible to eliminate this problem by modifying the polyvinyl alcohol size with small quantities of sorbitol. Addition of sorbitol in the quantity of 0.40 to 0.60 lb. per 100 gal. of size solution has been sufficient This small amount of sorbitol is enough to tie up any extracted borax but not enough to prevent the gelling reaction on the surface of the sheet.

The polyvinyl alcohol size has been generally applied from a water box on a calender stack. The size can be applied in any conventional manner, however, pro-

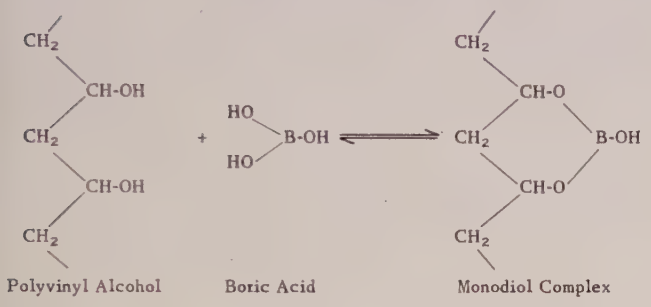


Fig. 10

vided the borax pretreatment has been made beforehand. The polyvinyl alcohol size has been applied by size press as well as by on- and off-machine coaters.

A SINGLE-STAGE ELVASIZE PROCESS

Solutions of boric acid and polyvinyl alcohol are compatible. Boric acid and polyvinyl alcohol react however, to form a monodiol complex (*2*): This reaction does not cross-link the polyvinyl alcohol chains, and only a slight viscosity increase results from the modification with boric acid. Up to 20% boric acid, based on the dry polyvinyl alcohol weight, can be tolerated before a salting-out effect causes precipitation of the polyvinyl alcohol.

When a polyvinyl alcohol solution modified with boric acid is made alkaline, the boric acid is converted to the borate form. This leads to the formation of the didiol complex of polyvinyl alcohol and borax, resulting in the cross-linking of polyvinyl alcohol chains and gelation of the solution.

Some alkaline grades of paper and paperboard are currently being produced. Sizing results similar to those which have been achieved with the two-stage application of the Elvasize process can be achieved with a single-stage application of a polyvinyl alcohol-boric acid mixture on alkaline substrates. This single-stage version of the Elvasize process has been demonstrated on alkaline board, both in the laboratory and in the mill.

Solutions of polyvinyl alcohol–boric acid mixtures

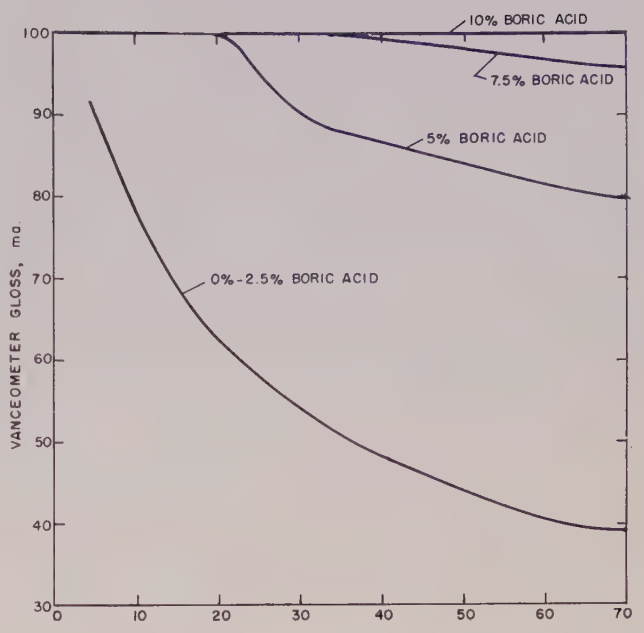


Fig. 11. Effect of boric acid concentration on oil absorption of alkaline board sized with single-stage Elvasize process (5% Elvanol 72-60)

Note: Boric acid concentration based on dry polyvinyl alcohol weight

are best prepared by dissolving the dry polyvinyl alcohol in a boric acid solution. The boric acid solution concentration should be adjusted to give the desired ratio of polyvinyl alcohol to boric acid in the final mix.

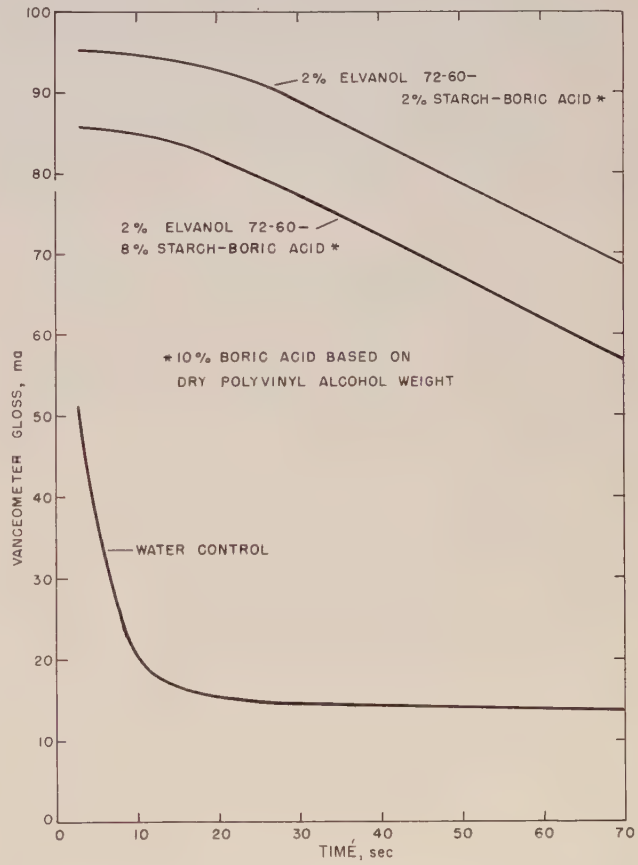


Fig. 12. Oil absorption of alkaline kraft linerboard commercially sized with the single-stage Elvasize process (starch modification)

Laboratory Evaluation

Samples of an alkaline board having a surface pH of about 9 were sized with equal amounts of five different solutions of 5% Elvanol 72-60. Four of the solutions were modified with boric acid in amounts ranging from 2.5 to 10.0%, based on the weight of the dry polyvinyl alcohol. After conditioning, the samples with the five different polyvinyl alcohol sizes were tested for Vanceometer oil absorption.

The Vanceometer data, plotted in Fig. 11, clearly demonstrate the effect of the boric acid concentration on the oil resistance of the polyvinyl alcohol size. As the boric acid concentration is increased, a greater degree of polyvinyl alcohol cross-linking occurs on the alkaline surface. This results in improved polyvinyl alcohol holdout, and consequently better oil resistance of the size.

Table II. Abrasion Resistance of Cylinder Kraft Linerboard

Size	*Total solids, %*	*Taber abrasion,[a] g. material lost per 1000 revolutions*	*Improvement, %*
Water control	—	0.5497	—
1 part Elvanol 72-60 1 part starch, 0.1 part boric acid,	4	0.3103	44
1 part Elvanol 72-60 4 parts starch 0.1 part boric acid	10	0.2814	49

[a] Abrasion test made with a 500-g. weight and "Calibrase" CS-10 wheel.

It was noted in this experiment that polyvinyl alcohol solution modified with 2.5% boric acid showed no improvement over the straight polyvinyl alcohol size. However, as the boric acid concentration is increased above 2.5%, the oil resistance improves, reaching complete oil holdout for 70 sec. with a 10% boric acid modification.

Mill Evaluation

A mill trial was made on an alkaline (pH 9) grade of cylinder kraft linerboard with the single-stage version of the Elvasize process. The purpose of this trial was to improve the abrasion resistance and printing properties of the board. Polyvinyl alcohol–starch sizes modified with boric acid were used in two runs, and board sized with water was used as a control in another run.

The first run was made with a size consisting of 1 part Elvanol 72–60, 1 part ethylated starch§, and 0.1 part boric acid at about 4% total solids. The second run was made with size consisting of 1 part Elvanol 72–60, 4 parts ethylated starch, and 0.1 part boric acid at about 10% total solids. Samples of board from these two runs plus samples with the water size were conditioned and tested. The Vanceometer oil absorption data are plotted in Fig. 12, and Taber abrasion (TAPPI Standard T 476 m-50) data are reported in Table II. A substantial improvement in oil resistance was achieved with the Elvasize process. Likewise, the abrasion resistance improved as much as 49%. With an approximate size consumption of 6 to 7 gal. per ton of paperboard, the cost of these treatments was in the range of $0.65 to 0.95 per ton.

§ Penford Gum 280 (Penick and Ford Ltd., New York, N. Y.)

SIDE EFFECTS OF THE ELVASIZE PROCESS

In most instances where the Elvasize process has been commercially evaluated and used, there have been few serious problems with side effects of the borax pretreatment. The alkalinity of the borax solution could affect the water resistance and brightness of certain grades of paper and paperboard.

Water Resistance

Most papers and paperboards are treated with an alum-rosin internal size for improving the water resistance of the sheet. Under the conditions of this treatment alum and rosin react to form aluminum resinates, which are electrostatically attracted to the paper fibers. The hydrophobic resinate molecules provide a water-resistant surface on the paper fibers. In the presence of strong acids or bases, hydrolysis of the aluminum resinates can occur, destroying the water-resistant properties of the sheet. It has been demonstrated in the laboratory that excess borax solution, like all other alkalies, will hydrolyze the internal size.

In practice, however, the application of the borax pretreatment with the Elvasize process has caused no apparent loss of internal size, in most applications. Probably excess alum and quick drying of the borax solution account for this.

If the borax pretreatment causes difficulties with the alum-rosin size, the following action should be taken. First, steps should be taken to ensure that the borax application is at the optimum level. Eliminating excess borax should alleviate most problems. If this is not enough, the borax solution can then be buffered to a lower pH (7.5 to 8.5) with a dilute mineral acid or with boric acid solution. As the pH of a borax solution is decreased, or the ratio of borax-to-boric acid is decreased, the gelling efficiency of the pretreatment is also reduced.

Brightness

With the exception of paper and paperboard containing bleached groundwood pulp, the borax pretreatment of the Elvasize process has no effect on the brightness of bleached paper and paperboard. Stocks containing bleached groundwood pulp, however, show a brightness drop due to the borax pretreatment. The brightness drop generally amounts to one or two points, depending upon the groundwood content of the board, the amount of excess alum in the board, and the concentration of the borax pretreatment.

G.E. brightness was measured on samples of bleached board from two mill trials with the Elvasize process. A bleached manila lined board (containing groundwood pulp) was pretreated with 5% borax solution. The G.E. brightness data in Table III show that a brightness drop of 1.4 points resulted from borax pretreatment. In a second trial on a solid bleached board (no groundwood) there was no brightness drop after the borax pretreatment.

It has been demonstrated in the laboratory that a pretreatment with 5% borax solution (pH 9.3) causes a two-point brightness drop on pure groundwood pulp,

Table III. Effect of Borax Pretreatment on the G.E. Brightness of Bleached Paperboard

	Board containing groundwood	*Board containing no groundwood*
Borax pretreatment	52.8	80.9
No pretreatment	54.2	80.9

but that a pretreatment with a 5% solution of a 50:50 mixture of borax and boric acid (pH 8) causes no brightness drop on the same groundwood pulp. Although this borax-boric acid combination is less efficient than straight borax as a pretreatment, it is still effective in controlling polyvinyl alcohol size penetration.

CONCLUSIONS

More than a year's experience with the Elvasize process in many paperboard mills throughout the country provides the basis for the following general conclusions:

1. The process for sizing paperboard for high-gloss printing gives quality improvements at lower sizing costs as compared with regular sizing methods.
2. In paperboard operations, the two-stage process generally can be applied on existing machine equipment.
3. In the Elvasize process, the polyvinyl alcohol size can be extended with starch in certain applications to give advantages in quality and costs.
4. The process has potential application in many fields for applying a barrier size against penetration of grease, solvent, oil, lacquer, coating formulations, and gases. The process can also be used for penetration control when polyvinyl alcohol is incorporated into coating systems which are applied to borax-pretreated surfaces.
5. The single-stage version of the process gives results on alkaline sheet comparable to the two-stage process on acid sheet.
6. The effect of the borax pretreatment on the alum-rosin size or the brightness of paper or paperboard can be eliminated by buffering the borax solution to a lower pH, or reducing the total amount of borax applied.

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Groundwood Pulp Fractionation and Screening with Pressure Screens at High Consistency

ARTHUR J. STERNBY and DONALD F. LEHMAN

Fractionation of groundwood pulps at high consistency using Selectifier pressure screens produces groundwood of controlled freeness and sliver content for high grade specialty papers and newsprint. Extensive studies on a commercial installation have shown that Selectifier screens are highly efficient when applied on groundwood furnishes for sliver removal. Ideal testing conditions were maintained on a high tonnage system, with complete records of freeness, flow rates, consistency, and sliver content. TAPPI Standard testing procedures and the Klemm sliver removal efficiency evaluation methods were employed in determining the Selectifier screen fractionation efficiency. The variables of hole sizes, reject rates, dilution methods and quantities, rotor peripheral speeds, number of foils, freenesses, consistencies, sliver contents, and pressures have been studied and evaluated. Some of the resultant advantages when all variables are properly utilized in a high-consistency pressurized screening system are: reduced decker, piping and pumping requirements, reduced space and horsepower requirements, reduced or eliminated screen dilution requirements and completely automatic operation of the entire screen room.

Extensive studies were conducted at a large newsprint and fine groundwood mill* to evaluate the fractionating, cleaning, and operating efficiences of Selectifier® screens on high-consistency groundwood. Pulp variables, as well as primary and secondary screen variables were studied to determine optimum operating conditions when screening mechanical groundwood pulp.

The term "fractionation," as used in this paper, differs from the normally accepted definition of screening. Screening usually refers to the removal of contaminating materials, such as shives and fiber bundles, or undefibered particles of wood. Fractionation means the removal of the materials normally removed in screening and, in addition, the removal of long-fibered, high-freeness pulp to produce a low-freeness, short-fibered pulp.

The purpose of the fractionation investigation was to determine the possibility and practicability of producing varying pulp specifications from a single grinder furnish used in the production of paper grades varying from newsprint to high-grade specialties.

The primary objective throughout this investigation was to obtain results at high consistency because of apparent benefits, such as reduced decker requirements, reduced screen and decker room space requirements, reduced pumping requirements, and reduced pipe line sizes.

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* Work Performed at Great Northern Paper Co., East Millinocket, Me.

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GROUNDWOOD SCREENING AND FRACTIONATION DEVELOPMENT PROGRAM

Initial Phase

The original objective of the groundwood screening studies was to determine if pressure screens could be employed in a high consistency, groundwood screening operation for the production of newsprint grades of paper.

These studies started several years ago. Progress was slow during the initial stages because of inadequacies throughout the test system and inconclusive testing and evaluating procedures. Flow and pressure meters with recording instruments were not available. Efficiencies were based on blue glass and handsheet evaluations; which are possibly satisfactory as a check for newsprint pulp quality, but are inadequate for extensive analytical studies.

The first phase did, however, prove that high consistency groundwood screening was feasible, and indicated that further studies should be made to determine the application of Selectifier screens for fine groundwood screening and fractionating. In addition, the first phase indicated the effect of many operating variables, the changes and refinements necessary throughout the entire test system and the type of procedures necessary to properly evaluate data.

Second Phase

The objectives of the second phase were threefold:

1. To determine the Selectifier screen efficiency and the effects of pulp, screen, and system variables when applied on mechanical groundwood for the production of newsprint. This was a continuation of the initial objectives under considerably improved control and evaluation conditions.

2. To determine the Selectifier screen efficiency and the effects of pulp, screen and system variables when applied on mechanical groundwood for the production of high grade, specialty papers.

3. To determine the Selectifier screening efficiency and the effect of variables when the unit is applied as a secondary screen, operating on primary-screen rejects.

METHODS OF DETERMINING SLIVER REMOVAL EFFICIENCIES

Two methods of determining the sliver removal efficiency of a screening unit were evaluated for their degree of accuracy. These are (1) the Klemm and Paterson method (*1*, *2*), and (2) the reject efficiency method.

Klemm and Paterson Method

The sliver removal efficiency method as presented by Klemm and Paterson was adopted for the second testing phase because it presents a reproducible quantitative method of evaluating TAPPI Bauer-McNett classifier data and procedures. Some of the equations taken from the literature (*1*, *2*) and those used in these studies are given below, with definitions pertinent to the efficiency calculations:

Inlet stock. Stock entering screen and assigned the value of 100 so that all other streams may be expressed as a percentage relative to the inlet stream.

Good stock. That stock which passes through the 14-mesh screen in a Bauer-McNett classifier under TAPPI Standard test conditions.

Silver content. Percentage of stock retained on the 14-mesh screen in fiber classifications using a Bauer-McNett classifier under TAPPI Standard test conditions.

Specific energy consumption. Horsepower-day per ton of accepts (moisture-free) consumed by the screen.

Sr. Sliver content or 14-mesh retention of rejects stream, %.

Se. Sliver content or 14-mesh retention of the inlet stock, %.

Sa. Sliver content of the accepted stream, %.

Le. The long fiber content or 28-mesh retention of the inlet stream.

La = Long fiber content. Percentage of stock retained on the 28-mesh screen in fiber classification using a Bauer-McNett classifier under TAPPI Standard test conditions.

Equations Used in Calculations

Accepted stock (a as % of feed)

$$a = 100 \times \frac{Sr - Se}{Sr - Sa} \qquad (1)$$

Sliver yield (Ys as % relative)

$$Ys = 100 \times \frac{Sr\,(Se - Sa)}{Se\,(Sr - Sa)}, \quad \text{or} \quad 100 \times \frac{Sr}{Se}\,r \qquad (2)$$

Good stock loss (Yg as % relative)

$$Yg = 100 - a\,\frac{(100 - Sa)}{(100 - Se)}, \quad \text{or} \quad Yg = r\,\frac{100 - Sr}{100 - Se} \qquad (3)$$

Long fiber yield (YL as % relative)

$$YL = a\,\frac{La}{Le} \qquad (4)$$

Reject stock (r as % of feed)

$$r = 100 - a, \quad \text{or} \quad 100 \times \frac{Se - Sa}{Sr - Sa} \qquad (5)$$

Dilution water consumption

$$Q = a\,\frac{(1/Y - 1/Z) + 100\,(1/Z - 1/X)}{6.02} \qquad (6)$$

where:

Y = accepts consistency
X = inlet consistency
Z = rejects consistency
6.02 = constant

a = accepted stock	= the relative percentage of stock accepted by the screen based on 100% as the quantity of inlet stock.
Ys = sliver yield	= relative percentage of slivers in the rejected stock compared to the slivers in the inlet stock; i.e., the relative percentage of inlet slivers that have been rejected.
Yg = good stock loss	= the relative percentage of good inlet stock which is rejected by the screen.
YL = long fiber yield	= relative percentage of long fibers in the accepted stock compared to the long fibers in the inlet stock (long fibers being 28-mesh retention on Bauer-McNett classifier)
r = rejected stock	= the relative percentage of stock rejected by the screen based on 100% as the quantity of inlet stock.
Q = shower or dilution water consumption	= U. S. g.p.m. per daily ton (moisture free) of inlet stock of shower or dilution water used in the screening.

Reject Efficiency Method

This method was evaluated during the second testing phase. It combines sliver percentages (relative %—14-mesh retention) of inlet and reject flows with a reject rate determined from flows and consistencies:

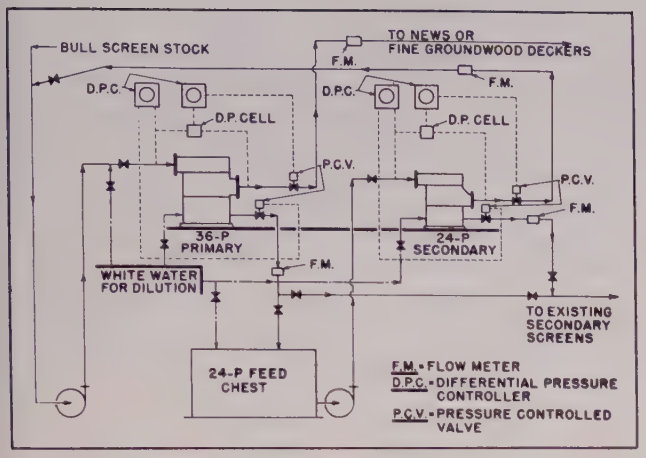

Fig. 1. Diagram of the selectifier screen system

Reject efficiencies

$$RE = 100 \frac{Sr}{Se} R$$

where

R = reject rate, % relative, calculated from flows and consistencies.

This differs from the Klemm method where the sliver yield efficiency is determined from sliver percentages only [see equations (2) and (5)]. It was found that the results from the reject efficiency method were very erratic. Efficiencies of 100% and higher were reached during several series of tests. This is impossible. It was concluded that the reason for the erratic results was the compounding of additive but unrelated errors when sampling, measuring and weighing. This method was discarded in favor of the Klemm method, which was always reasonable and reproducible.

TEST SYSTEM

Figure 1 shows the Selectifier screen system used in the second phase of the testing program. The 36-P screen was the primary screen and the 24-P screen was used as a secondary screen (Fig. 2). These screens were slightly modified to incorporate a dilution area in the lower portion of the units. These units and the controls were tested and all known variables were evaluated. The accepted stock from the primary 36-P

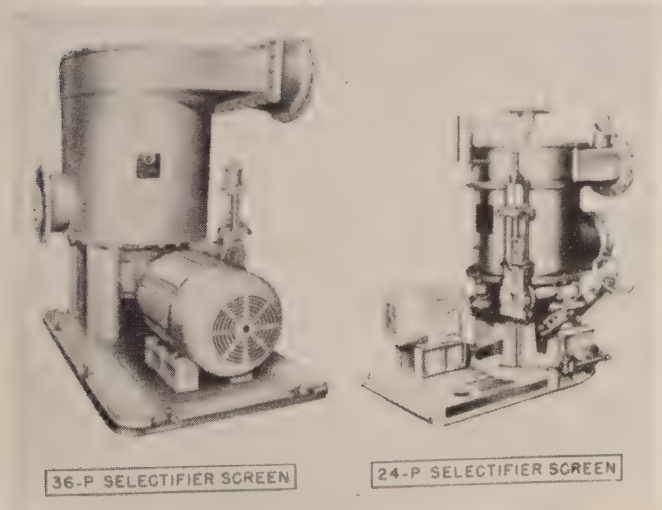

Fig. 2. The Selectifier screens

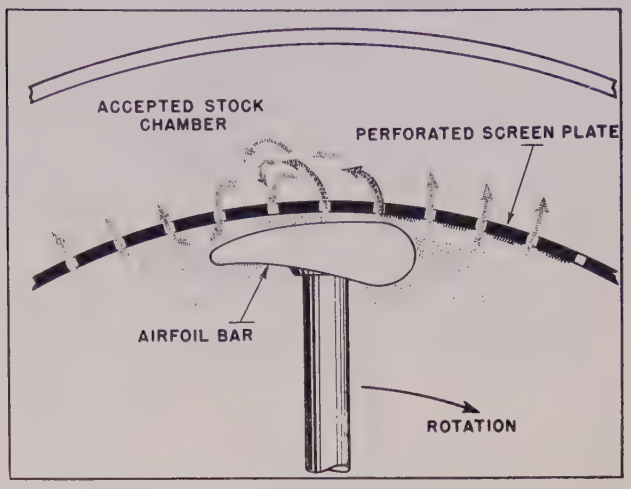

Fig. 3. Principle of screening operation

screen was metered to the deckers and the rejects were metered to the secondary 24-P screen. The concentrated rejects from the 24-P screen were metered to the existing secondary screening system and the secondary 24-P screen accepts were metered back to the 36-P screen inlet.

Orifices with recording instruments were used to measure and record the white water flows. Magnetic flow meters with recording instruments and pneumatically operated control valves were employed to record and meter the accepted and rejected flows from both screens.

Selectifier Screen Operation

The Selectifier screens (Fig. 2) used in these tests, are vertical, totally enclosed, rotary screens which operate completely full of stock and under pressure at all times. The pulp furnish enters the tangential inlet, spirals downward and outward through the screen-plate openings, discharging through the outlet located on the main cylindrical body housing. Materials which do not pass through the openings in the screening cylinder are continuously forced downward into the reject volute section by the downward stock flow and by the sloping foils which are mounted on the revolving rotor. High-specific-gravity materials pass through an opening in the bottom of the volute and are collected in the trash box. Lighter materials, such as shives and slivers, are removed continuously through the extended volute end. The heart of the screening operation is based on the fluid dynamics airfoil principle (Fig. 3) used in the aircraft industry to create a partial vacuum above the wing of an airplane.

The partial-vacuum pulse created by the foils, when they pass a given perforated area, must be great enough to overcome the differential pressure across the screen plate. The foils also direct the flow of the rejects downward to the volute section at the bottom of the screen where they can be removed. This action keeps the screening surface clear, thus permitting high consistency screening with a minimum consistency drop across the screen plate.

Screen Modifications. The 36-P and 24-P screens were slightly modified to determine the benefits of internal screen dilution or shower water as commonly used in other types of pulp mill screens. Various types

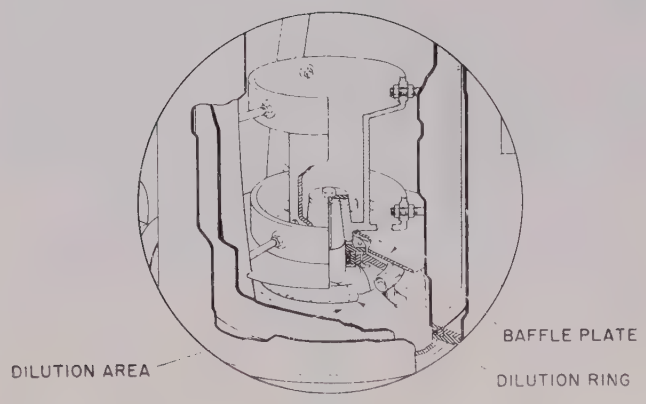

Fig. 4. Dilution ring and baffle plate

of baffle plates were attached to the bottom of each rotor cage to evaluate methods of retaining the dilution water in the lower portion of the unit where the rejects are concentrated.

System Controls. The necessary flow meters, controlling and recording instruments, and pneumatically operated valves, were installed in the accepts and rejects flow lines to evaluate the operating characteristics of a screening system when completely automated and to study properly those interrelated variables which were subject to change in varying degrees.

Screen Controls. The operation of the control valves on each of the screens is illustrated schematically in Fig. 5. The pressure drop across the Selectifier screen is measured with a differential pressure (DP) cell. The output from the DP cell is transmitted to a pressure controller which modulates the screen accepts flow-control valve to hold the pressure drop constant. The screen inlet pressure is measured by a second pressure-recorder controller which modulates the reject flow-control valve to hold the inlet pressure constant. If the pulp on the unscreened side of the screen plate begins to thicken, the pressure drop across the screen starts increasing. When this increase goes beyond the instrument differential set point, the instrument throttles the accepts flow-control valve to bring the differential pressure back to the set point. While the foregoing functions are taking place, the inlet pressure increases with the throttled throughput. The pressure controller on the inlet measures this pressure increase

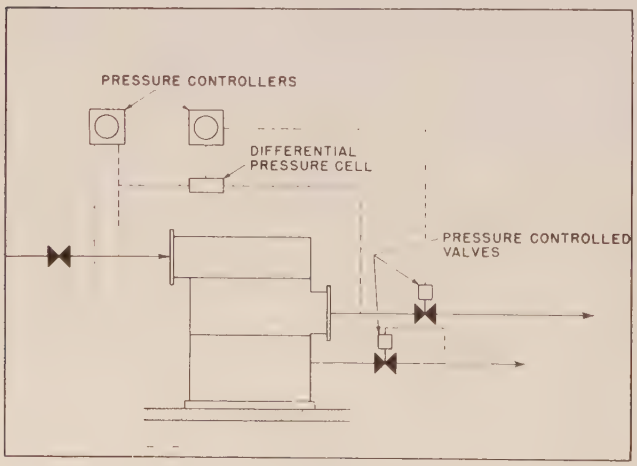

Fig. 5. Diagram showing the operation of the control valves on the screens

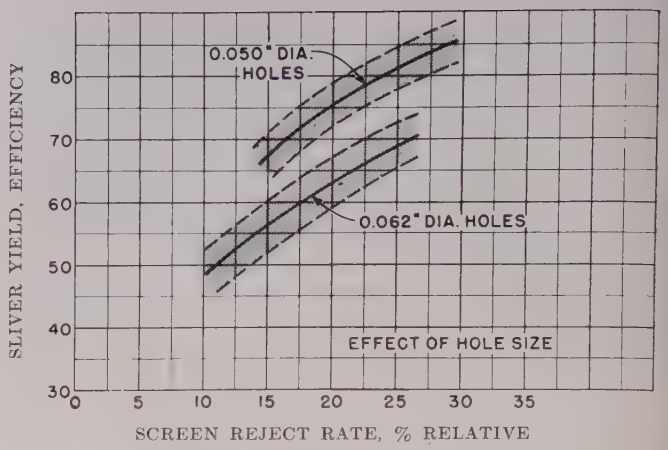

Fig. 6. Effect of hole size on screening efficiency

and opens the reject valve to hold the inlet pressure of the unit at the instrument set point. This purges the screen through the reject line, preventing a plug.

Variables Studied

Screen Operating Variables

1. Reject rates
2. Hole size
3. Foil clearance settings
4. Rotor speed
5. Dilution
6. Number of foils
7. Differential pressure
8. Flow rates and capacity
9. Inlet pressure

Pulp Variables

1. Sliver content
2. Freeness
3. Consistency
4. Temperature

The screen operating variables are controllable and, therefore, they could be duplicated at any time. Owing to the lack of control over pulp conditions, it was impossible to exactly duplicate the pulp variables.

DISCUSSION OF RESULTS

Controls

The automatic control of the Selectifier screens proved very successful. The differential pressure controller on the accepted-stock control valve and the inlet pressure controller on the reject-stock control valve operated trouble-free over extended periods of time and under the most severe screening conditions. Extreme consistency variations and surges of unusually high percentages of slivers were experienced at times. The 36-P feed-chest level was dropped and emptied during high tonnage runs to satisfy the screen demand. In doing this, a layer of concentrated slivers and pieces of wood that had settled to the chest bottom were delivered to the screen. Extreme consistency variations, usually at cleanup time in the grinder room, were also experienced. The controls on the screen would function throughout these extreme consistency and sliver concentration variations to prevent a plugging condition and maintain production of accepts quality.

Screen Operating Variables

Reject Rate. The percentage of inlet pulp that is removed from a screen as reject material is most influential in its effect upon screening efficiency. It is also a controlled operating variable which can be changed while holding all other screen variables constant. For these reasons, efficiency versus reject-rate

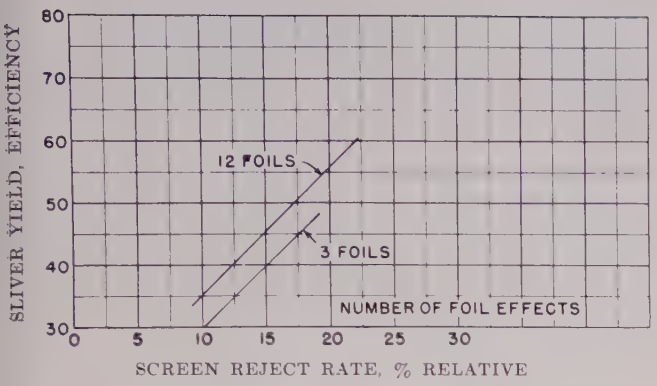

Fig. 7. Effect of increasing the number of foils on screening efficiency

curves were plotted to illustrate the effect of the screen variables. This made it possible to determine the most efficient operating conditions for the Selectifier screens. After determining this, we were in a better position to determine the effect of the pulp variables. Studies to date indicate that the optimum operating reject rate is in the order of 15 to 25% by weight of inlet pulp. This could vary considerably, depending on the required end-product and the condition of the screen inlet pulp.

Hole Sizes. Figure 6 shows the effect of hole diameters on efficiency. Screening efficiency is improved by decreasing the diameter of the holes in the cylinder when maintaining a constant reject rate. It can be seen in Fig. 6 that equivalent efficiencies can be obtained with either the 0.062 or 0.050 in. screen plate by changing the reject rate in either case. The minimum reject rate must be increased as the hole size is decreased to prevent plugging. The choice of hole size can be determined only after considering the characteristics of incoming pulp, pulp cleanliness or fractionation desired, necessary reject rates and the capacity requirements.

Number of Foils. Increasing the number of foils increases the sliver removal efficiency of the screen. This can be seen in Fig. 7, where two primary-screen efficiency curves are shown, one for three foils and the other for 12 foils. Increasing the number of foils slightly increases the horsepower requirements.

Foil Settings. A study of foil-to-cylinder clearances has shown that efficiences were improved as the clearance settings were reduced. Maximum efficiencies were obtained when a gap of approximately 0.025 to 0.030 in. was reached. Changes in clearance settings also affect horsepower requirements and differential pressure. Figure 8 shows the effects of clearance set-

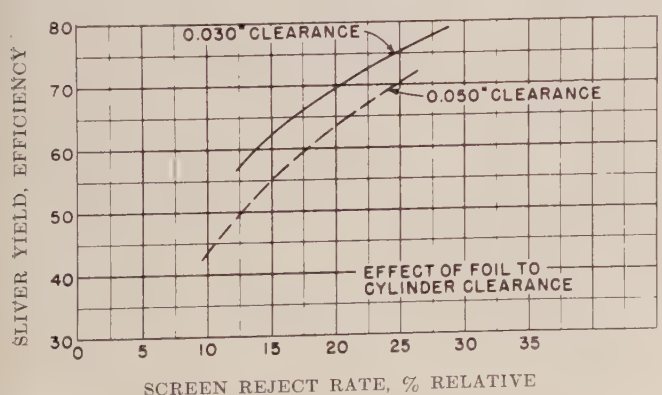

Fig. 8. Effect of foil-to-cylinder clearance on screening efficiency

36-P Selectifier Screen, 0.062-in. Diam. Holes, Foil Velocity = 2600 f.p.m.

Clearance, in.	No. of bars	Differential pressure, p.s.i.	Consumed hp.
0.185	6	4.54	55
0.070	6	2.14	60
0.050	12	1.12	63
0.030	12	1.0	67

Fig. 9. Effect of clearance settings on horsepower requirements and differential pressure

tings on efficiency. Figure 9 shows the effect of clearance settings on horsepower requirements and differential pressure.

Rotor Speed. The study of screen variables has shown that capacity is improved as the rotor peripheral speed is increased. The rate of capacity increase tends to level off at a peripheral speed of 2600 f.p.m. The horsepower requirements also increase with the increased peripheral speed. It is indicated that the optimal peripheral speed is in the order of 2600 f.p.m. on a groundwood pulp.

Dilution. Several methods were tested. It was determined that the most satisfactory arrangement should incorporate a dilution ring and baffle plate as shown in Figure 4 so that uniform distribution of the dilution water is maintained. The benefits obtained from dilution are slight improvements in efficiency and reductions in good stock losses. Dilution also helps to control reject pulp consistency. Figure 10 shows the maximum efficiency improvement due to dilution found throughout the tests under identical operating conditions.

Differential Pressure. The differential pressure across the unit, within a range of 0 to 2.5 p.s.i., has little or not effect upon the screening efficiency. The capacity or flow rate through the unit was controlled by the differential pressure in this range. Increasing the differential pressure beyond 2.5 p.s.i., in the normal consistency operating range of 1 to 1.7% consistency using 0.062 to 0.050 in. perforations, increased the capacity very little and reduced the cleaning efficiency of the screen. The operating differential pressure is also related to consistency. As the consistency is reduced, the differential pressure drops if the flow rate is maintained constant. The reverse is true if the consistency is increased.

Flow Rates. The flow rate through the 36-P screen has little or no effect upon the efficiency when all other variables are maintained constant. Actually, the

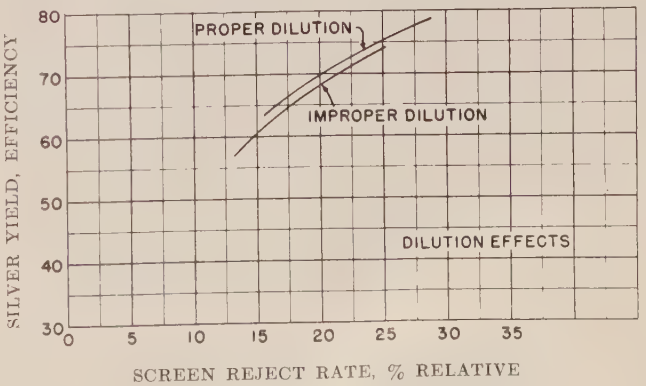

Fig. 10. Effect of dilution on screening efficiency

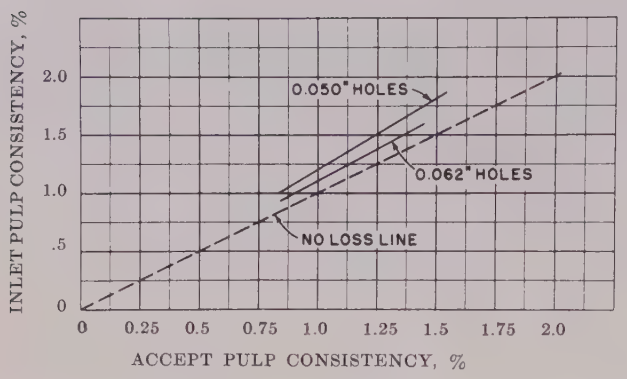

Fig. 11. Relationship between hole size and inlet and accepts consistency

maximum flow rate is almost entirely dependent upon two variables: hole size and consistency. This means that the 36-P screen can be operated at top efficiency over a wide range of capacity. The capacity performance within the range of variables studied indicated that the 36-P screen is capable of fractionating and screening groundwood pulps at production rates in the order of 150 to more than 230 tons per day.

Inlet Pressure. It was possible to operate at any pressure level from 5 to 30 p.s.i., which was the pressure limit obtainable, with no effect on the efficiency or operation of the Selectifier screens. It is indicated from this and other studies that operation at higher inlet pressure levels would not adversely affect the efficiency or operation of the screens.

Pulp Variables

Sliver Content. The affect of sliver content variations in the pulp as supplied to the screen is probably the most difficult of all the pulp variables to analyze. The results of data from many hundreds of tests still are inconclusive. Undoubtedly, the use of computers will be required before the questions concerning this variable are answered. However, the tests indicate that as the sliver content of the inlet pulp is reduced, the sliver removal efficiency is slightly improved.

Freeness. The freeness of the inlet pulp has an effect on cleaning efficiency and on the drop in consistency across the screen. As the inlet freeness is reduced, the efficiency improves and the consistency drop increases.

Consistency. A very important consideration in this work was the consistency drop from the screen inlet to the screen accepted pulp. This is directly related to the decker economics mentioned previously. Figure 11 shows how inlet and accepts consistencies are related to the hole size in the screen plates. As would be expected, the consistency drop is greater with the smaller hole size.

A minimum change in consistency from the inlet to the discharge is important to obtain increased decker capacities and corresponding economies. It is important to maintain consistencies of 1.5 to 1.7% from the grinder room and coarse screening system. Nominal internal screen dilution requirements are important to keep the consistency drop at a minimum.

There was no noticeable affect on the cleaning efficiences or on the fractionating abilities of the Selectifier screen due to consistency changes in the ranges of these tests.

Temperature. No detailed temperature study was conducted since temperature was not considered a major variable. This work was done within the range of approximately 140 to 160°F. When additional groundwood screening trials are conducted, an investigation of temperature should be considered.

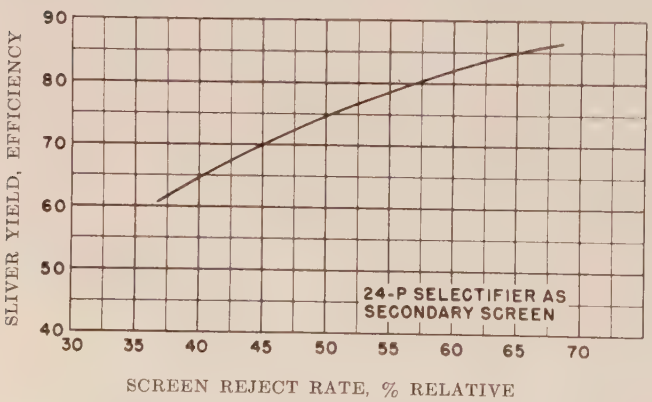

Fig. 12. Efficiency of the 24-P secondary rejects screen, using 0.062-in. holes and four foils

Secondary Screening

The objective of the secondary screen studies was to determine the Selectifier screen efficiency and the effect of variables when the unit was applied on primary-screen rejects. The secondary screening trials have shown that the results of the secondary screen variables follow the same general trends of primary screen variables.

The operating objective of a secondary screen is to further concentrate the rejects from the primary screen with a minimum of good stock loss from the overall screen system. The quality of the accepts from the secondary screen must be at least as good as the primary-screen feed pulp, if the secondary screen accepts are being recirculated back to the inlet of the primary unit. This is necessary to prevent a continuous buildup of reject materials in the screening system.

The 24-P Selectifier screen was operated very satisfactorily as a secondary screen. The findings to-date indicated that four foils on the rotor turning at 400 r.p.m. for a foil peripheral speed of approximately 2500 f.p.m. will give the best results. The hole size will depend upon the concentration of slivers in the accepts, the degree of cleaning necessary, and the desired concentration of slivers in the rejects, which is controllable (within a range) by the reject rate.

Figure 12 shows the efficiency of the 24-P secondary rejects screen, using 0.062-in. holes and four foils.

SUMMARY

The results of these tests have shown that high consistency pressurized screening and fractionation with Selectifier screens is a proved accomplishment. Screening and fractionation has been controlled to a degree which permits the production of both newsprint groundwood and higher grades of groundwood from a single grinder furnish. Pressurized and high consistency screening has set the pace for groundwood screening in the future.

The additional benefits obtainable are listed as follows:

1. Reduced decker requirements.

2. Reduced pump and pipe requirements.
3. Reduced space requirements.
4. Enclosed system reducing air entrainment, foam, and slime problems.
5. Large capacity per installed unit.
6. Lower installation cost per ton.
7. Flexibility in choice of location.
8. Directly controlled reject rates.
9. Automatic controls of flows and pressures.
10. Less operator supervision.
11. Limited and optional use of dilution water.
12. Low power consumption per ton.
13. Low mechanical maintenance.

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The Black-Clawson Co. gratefully acknowledges the contributions of the top management of the Great Northern Paper Co. and particularly the farsightedness required to initiate such an important research program on a commercial scale.

The Pulping and Reclaiming of Fiber from Plastic Coated Board and Paper

JOHN W. DOW and A. J. FELTON

Coated boards fall into two groups (I and II) as far as coating removal is concerned. When slush-pulped the coating of I tends to remain in large flakes, screening readily. In II the coating breaks up into small pieces and a centrifugal-type cleaner can be used for separation. Successful runs using a 5-ft. diam. Hydrapulper equipped with a Yokes-type rotor and perforated bed plate have been made on polyethylene-coated board. The coating remained in the tub and the fiber was extracted continuously through the bed plate. The coating and a small percentage of fiber was then flushed out of the tub. Water temperatures up to 190°F. were used, and on some runs 5% caustic soda was added to disperse the ink and speed up the slushing process. Board coated with polyvinyl compounds presents more difficulties and additional screening was sometimes required. Laminated board containing glassine, Saran, and cellophane was pulped and clean fiber extracted, with good results. Here the loss of fiber was somewhat higher. Coated carrier board having wet strength properties was batch-pulped. Alum and hot water were used and approximately 100% fiber separation was obtained in 20 to 25 min. The coating broke up to very small particles and the entire slurry pumped through a centrifugal-type cleaner with approximately 90% coating removal. In the re-use of this fiber the board would necessarily be coated, making the small particles not objectionable.

TECHNOLOGICAL advances in the field of packaging, box and bag making, and in other areas of paper converting have resulted in many new uses for paper and paperboard. Not only this but economies have been made, in many instances, in both material cost savings and faster production rates and consequent lower production costs by using coated and laminated papers and boards where other materials were used previously.

However, improvements in one direction sometimes bring on problems in other directions. Polyethylene, polyvinyl compounds, cellophane, and other films and coatings laminated to or deposited on paper and board are most difficult to handle for the papermaker using wastepaper in his furnish. These films and coatings are absolutely useless to him as papermaking materials. Furthermore they do not settle out in junk removal equipment, and do not screen out easily with other fractions of light-floating or low-specific-gravity trash. The bits and pieces of plastic that become broken down and pass through the cleaning equipment show up as specks in the finished board.

On the other hand, much of the paper and board used in plastic coated packaging and other types of converting is of the highest quality bleached pulp. The user of wastepaper needs this valuable material. He cannot afford not to use it. Thus, he finds himself on the horns of a dilemma; he needs the pulp because of its low price and high fiber value but cannot successfully cope with the plastic films and coatings.

Experience in the field of wastepaper handling shows that what is needed by the papermaker using waste materials is an auxiliary system of stock processing which will permit him to remove the plastic films and coatings from the paper or board, divert them to waste, and reclaim the valuable pulp fiber. Thus, he might deliberately purchase waste of this sort and process it separately to his distinct financial advantage.

Our quest for methods of reclaiming valuable fiber from plastic-coated board started in 1945 in Carthage, N. Y. Here with a small installation we learned that plastic-coated papers can be processed and that the coating falls into two categories. In one group, polyethylene(PE), the coating breaks up into large enough pieces to be screened out. In the other group, polyvinyl chloride(PVC), the coating often breaks into many small particles making it impossible to use a screen to separate fiber from coating. For this second group the high velocity centrifugal-type cleaner does not do an effective job because of low specific gravity of coating, 0.86 to 0.9.

In some cases a combination of screens and centrifugal cleaners is required. In our work we discovered that proper conditions at time of pulping will prevent

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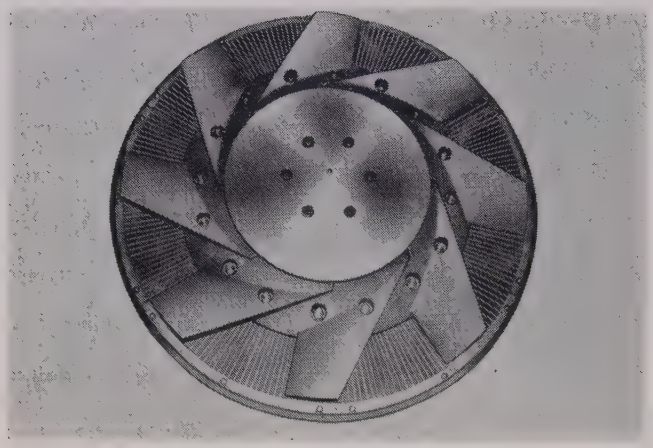

Fig. 1. The Vokes-type rotor

fracturing of PE and formation of very thin small particles.

EQUIPMENT USED

Different furnishes, diced polyvinyl, diced polyethylene and sheet or rolled PVC and PE or mixture of both, were defibered in a 5-ft. diameter vertical Hydrapulper. The Hydrapulper is equipped with a 24-in. diameter Vokes-type rotor with a peripheral speed of approximately 2400 f.p.m. The Vokes-type rotor (Fig. 1) has heavy, curved arms extending out from the center which act as pumping vanes as well as defibering vanes as the arms pass over the stationary extractor plate. The extractor plate has $^1/_8$-in diameter extraction holes and is designed for continuous extraction.

Figure 2 is the laboratory pilot system flow diagram. It shows that the tub is equipped with a large dump valve through which the coating collected in the tub may be flushed out periodically. This material may be dewatered in a drain pit or carried out by a junk remover. On some of the test runs a Selectifier screen was used to separate the good fiber from the plastic coating remaining after the stock had been extracted through the $^1/_8$-in. diameter holes in the Hydrapulper.

The pulping and primary screening through the perforated extractor plate is more or less a continuous operation. This includes continuous extraction of the fiber and washing out the remaining free fiber at the end of the pulping cycle and disposing of the collected coating film. The pulper is then refurnished for another run starting as a batch-type run and changing to continuous operation at extraction time. The free fiber from the pulping operation is collected in a chest, diluted to screening consistency and pumped continuously through fine screens, or through a centrifugal cleaner as the case may be.

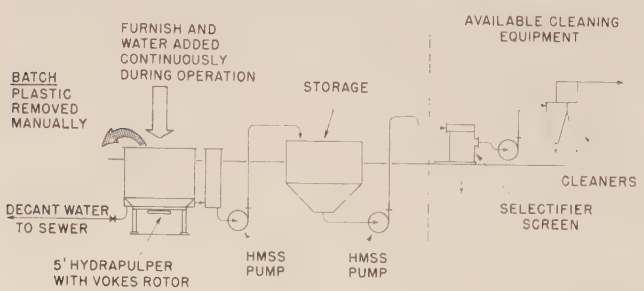

Fig. 2. Flow diagram of the laboratory pilot system

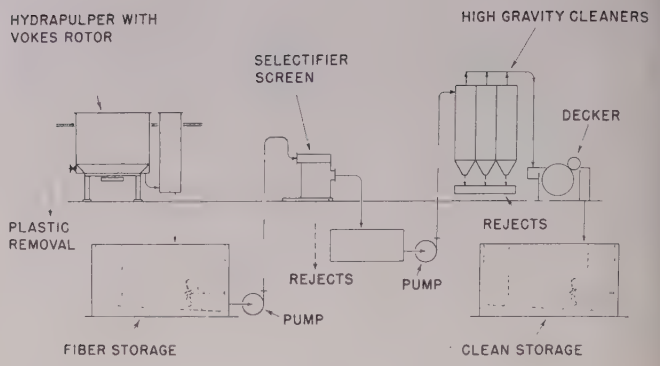

Fig. 3. Flow diagram of a commercial system

Most polyethylene-coated board can be defibered readily in 15 to 20 min. using water at temperatures ranging from 70 to 190°F., depending upon the specific coating formulation. During this initial stage of pulping the coating breaks into flakes and large pieces, and fiber separation is almost complete.

The regulating gate is then lowered and continuous extraction started. Continuous extraction is carried on for approximately 30 min. in the lab unit (longer, commercially) with furnish and water being added to maintain 5 to 6% consistency in the tub. When the plastic coating loads up in the tub, furnish is discontinued, water is continuously added in order to drop the consistency in the tub and wash the remaining free fiber out through the extractor holes. Approximately 90% of the fiber may be reclaimed in this manner.

Recently, printed cartons with polyethylene coating over the ink have appeared on the market. When this material is encountered, 5% caustic soda can be added. This speeds up the pulping process and reduces the power required. In general, approximately 4 hp. per ton per day are required when caustic soda is used and 6 hp. per ton per day when caustic is not used.

The clearance between the rotating arms and the bedplate is very important. This clearance directly affects the particle size of the coating and also the degree of fiber separation. Because of the variation in plastic coatings, results will vary somewhat. On a run of polyethylene-coated milk bottle clippings, samples taken from the regulating box during continuous extraction were free of any coating particles.

It is more difficult to get separation of fiber and coating when running PVC-1-coated sheets. After 15 min. pulping, the furnish is only 60 to 70% completely defibered. Much of the PVC coating forms strings which can be screened out. However, some of the coating breaks off into small pieces. More work needs to be done on this particular furnish with the use of a small hole screen, or possibly the use of a centrifugal-type cleaner, or both.

Coated laminated boards containing glassines, Saran coatings, and cellophane were pulped and then continuously extracted. Samples at the regulating box showed some small particles coming through, which indicates that centrifugal cleaning would be necessary before the fiber could be re-used. The loss of fiber with this type of coating is higher than when polyethylene-coated board is run.

Runs have been made on bleached and unbleached plastic laminated kraft papers. Operating conditions were altered somewhat because the pulping was done

with water temperatures of 70 to 75°F. After 20-min. pulping at a consistency of 4.5%, the consistency was reduced to less than 2% and continuous extraction started. After most of the free fiber had been extracted, additional water was introduced several times in order to obtain all the free fiber possible. The extracted stock was collected in a chest and further diluted to 0.7% consistency, and then pumped through the Selectifier screen.

Since the Hydrapulper had retained most of the coating material there was very little left for the screen to reject. In later runs coating material was deliberately put into the chest feeding the screen to determine the effectiveness of the screen. Samples taken showed no coating left in the screened stock.

Beer and soft drink carrier board was processed through the lab equipment, and in this particular case the coating broke up into many small particles. The surface of the carrier board is printed with several colors, varnish, etc., and the board contained a waterproofing agent, a synthetic binder, and acrylic resin. In order to pulp this wet-strength furnish, the temperature was held at 175 to 180°F. and the pH was reduced to 3.7. Complete fiber separation was obtained in 20 to 25 min. Most of the coating was in very small particles. However, some of the flat particles were $^1/_{16}$-in. wide.

This slurry was diluted to less than 1% consistency and pumped through the centrifugal cleaner where approximately 90% of the coating was removed. Reuse of this fiber would be restricted to some extent, as far as top liner is concerned, because of the extreme difficulty of coating removal.

CONCLUSIONS

Realizing that there are now many variations in polymer coatings and that there will be many more in the future, we believe it is possible from a practical standpoint to reprocess polymer-coated board and paper with the proper equipment and proper use of that equipment.

A flexible system (Fig. 3) should include a pulper and both a screen and centrifugal cleaner. This would make it possible for the operator to use only the pulper on certain grades; the pulper followed by the screen on others; the pulper followed by both a screen and a centrifugal cleaner on others; the pulper followed by a centrifugal cleaner only on others.

The use of these different combinations will, in general, cover most furnishes and make possible the reclamation for re-use of fibers which in the past have been lost to the paper industry.

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Studies in Interfiber Bonding of Paper

The Use of Optically Bonded Areas with High Yield Pulps

PHILIP LUNER, A. E. U. KÄRNÄ, and C. P. DONOFRIO

Although the relationship between bonded areas and strength properties has been investigated for chemical pulps, such data are absent for high-yield pulps. This investigation was designed to explore the use of optically bonded areas and its relationship to the mechanical properties of high-yield pulps. The mechanical properties (breaking length, Young's modulus, *E*) and optical properties (specific scattering coefficients) of white birch (*Betula papyrifera* Marsh) cold soda pulps produced by successive delignifications with sodium chlorite were determined at various levels of refining and wet pressing. The method of Ingmanson and Thode for measuring interfiber bonding was found inadequate for all the pulps. Values for the water-dried surface area of the pulps were obtained by extrapolating a plot of *S* vs. *E* to *E* zero. This plot was made on the basis of equal refining of the pulps. Bonded areas were calculated. Young's modulus was found to be a linear function of the bonded area irrespective of the lignin content, extent of refining or wet pressing. This result is in line with the close relation found between modulus *E* and sheet density, and indicates the importance of the latter in determining the bonded area of these high-yield pulps. The concept of bond density is discussed.

The strength of a paper sheet can be considered to reside in the strength of the individual fibers, the strength of the fiber-to-fiber bonds and in the distribution and orientation of the fibers in the sheet. It has been shown by a number of workers (*1–3*) that hydrogen bonds are the main forces in fiber-to-fiber bonding. These bonds are formed during the drying process with surface tension forces bringing the fibers and the fibrils initially into close contact. The extent of bonding can be affected mechanically by beating and wet pressure, or chemically by modification of the cellulose. The most important and most difficult factor to evaluate quantitatively in paper is the extent of interfiber bonding and its importance to sheet strength. There are a number of empirical tests which are used in the paper industry which measure interfiber bonding. However, these tests are quite complex and difficult to analyze. The tear test, the delamination test and the tensile test are among these.

By far the most comprehensive method of measuring interfiber bonding is that developed by a number of workers at the Institute of Paper Chemistry (*4–6*). The underlying assumption of this method is that the extent of the interfiber bonding is determined by the contact surface areas of the fibers, i.e., the bonded areas. The problem then becomes one of estimating this area.

Parsons (*4*), on the assumption that only free surfaces scatter light, estimated the bonded areas as the difference between the total surface area of the fibers determined by the silvering method (*7*), and the unbonded area in the paper sheet. The latter was obtained by

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Table I. Delignification of Pulps Using Sodium Chlorite and Analysis of Resulting Pulps

Pulp no.	Based on original ovendry pulp: $NaClO_2$ applied, %	Based on original ovendry pulp: Consistency, %	pH	Temperature, °C.	Based on resulting ovendry pulp: Lignin, %	Based on resulting ovendry pulp: Pentosans, %	Based on resulting ovendry pulp: Cross and Bevan cellulose, %
I	..	..	..	..	19.0	12.8	68.2
II	45	2	4.0	65 ± 5	12.0	11.4	76.6
III	45	2	3.8	65 ± 5	2.3	8.0	89.7

assuming that the ratio between the total surface area and the unbonded area in a normal sheet is the same as the ratio between the scattering coefficients of unbonded sheet (from butanol) and the scattering coefficients of normal handsheets. The fact that the scattering coefficients are true functions of the external surface area was established when Haselton (*6*, *8*) showed that a linear relationship exists between the scattering coefficients of water-dried handsheets and B.E.T. areas.

Haselton (*8*), and later Ingmanson and Thode (*5*) showed that there is a difference in the behavior of fibrils dried from water and those dried from a nonpolar solvent. They concluded that the use of specific scattering coefficient values for fibers (dried from butanol) in the final analysis gives spuriously large values of interfiber bonding, and that the surface from which to subtract the unbonded area should be the external surface of water-dried fibers.

Ingmanson and Thode (*5*) in their studies on interfiber bonding with a bleached chemical pulp varied the degree of bonding by beating in a ball mill and wet pressing. Upon plotting tensile strength against the scattering coefficient of the same handsheets the points fell on one common curve from which the extrapolation of the scattering coefficient at zero breaking length could be obtained. The extrapolated specific scattering coefficient value, S_0, was considered to correspond to that of totally unbonded fibers. A single S_0 value independent of the degree of beating was explained as the result of the rebonding of the fibrils to their parent fiber when dried from water. They considered that the strength of fibers, fiber length, bonding strength and sheet formation remained constant throughout all the experiments.

Swanson and Steber (*11*) have recently extended the work of Ingmanson and Thode. In this work a Valley beater was used to refine three widely different types of pulp. The linear correlation found by Haselton (*6*) between optical scattering coefficients and B.E.T. absorption areas was confirmed. This enabled Swanson and Steber to convert optically bonded areas to true areas. The proportionality constant relating the two properties varied with the type of pulp, but approached a value of 0.044 at longer wavelengths. The scattering–tensile strength relationship was similar to Nordman's (*9*, *10*) and showed much more scattering of data than the study of Ingmanson and Thode, presumably caused by the different beating action and type of pulp.

While Ingmanson and Thode (*5*) obtained a single curve relating tensile strength and bonded area, Swanson and Steber (*11*) found a curve for each beating interval. This was explained as a result of increased bond density produced on beating.

The present investigation was undertaken primarily to explore the use of optically bonded areas to describe interfiber bonding for pulps ranging from a mechanical to a delignified pulp. It was felt that by using such a large range of pulp fibers possible limitations and improper assumptions in the scattering method to determine surface areas would be revealed.

Table II. Freeness Development of Experimental Pulps Processed in the Pebble Mill

Pulp no.	Letter designation	Lignin content, %	Beating time, min.	C. S. freeness at 20° C., ml.
I	A	19.0	0	680
	B		100	680
	C		250	590
	D		500	410
II	A	12.0	0	690
	B		100	680
	C		305	580
	D		565	410
III	A	2.3	0	660
	B		50	640
	C		160	590
	D		850	370

MATERIALS AND EXPERIMENTAL PROCEDURES

Cold soda pulp from white birch (*Betula papyrifera* Marsh) was prepared in such a manner as to provide good fiber separation and to eliminate as much as possible the bruising of fibers. These pulps had been used in a previous morphological investigation (*20*).

Chips, 200 g., $^3/_8$ in., were soaked in 800 ml. of 6.5% NaOH for 30 min. and then kneaded mechanically for 60 min. at room temperature. The semipulp was then passed through a Sprout Waldron laboratory disk mill at a clearance of 2.5 mils and then washed and neutralized in SO_2 water. A yield of 77.4% was obtained. The pulp was then bleached with H_2O_2 to improve the accuracy of the optical measurements. The bleached pulp, designated as no. 1, was then delignified to different degrees with acidified sodium chlorite. Table I lists the conditions of delignification and the pulp analysis. These were done in accordance with TAPPI Standards. The pulps were then refined to the same four levels of C.S. freeness by ball-milling with stone pebbles. This was done so that the bonding potentialities for all pulps could be compared at the same freeness level. These data are shown in Table II.

Handsheets were prepared by the conventional TAPPI Standard method except that wet pressures of 0.5, 15, 50, 150, and 960 p.s.i. were used. Prior to wet pressing a wet filter paper was placed between the sheet and the polished metal plate. This was done to eliminate gloss which affects the optical measurements (*12*).

Testing of the Handsheets

From the conditioned paper samples, five test strips 15 by 127 mm. were cut from a handsheet and each strip was treated individually in the physical testing. However, for the thickness measurement and density calculation all five strips were handled together as specified in TAPPI Standard T 220 m-53.

The optical measurements from which scattering coefficients were calculated were done with monochromatic light (457 mμ) in a Beckman DU spectrophotometer. A special adapter was constructed with which it was possible to measure reflectance values on the same strips that were subsequently used in the tensile test. The R_0 and R_∞ values were determined, the former as an average of 25, the latter as an average of 10 measure-

Table III. The Maximum Deviation of Specific Scattering Coefficient Values for the Wet Pressure Levels 0.5 and 960 P.s.i. at Different Lignin Contents

Pulp designation	Wet pressure, p.s.i.	R_∞, %	Scattering coefficient s, cm.²/g.	Maximum deviation of s, cm.²/g.
I A 1	0.5	49.06	378	13
5	960	45.97	246	4
I D 1	0.5	53.30	483	20
5	960	43.70	210	3
II A 1	0.5	61.18	362	7
5	960	54.10	201	1
II D 1	0.5	62.10	383	7
5	960	45.00	127	1
III A 1	0.5	66.18	344	3
4	150	60.40	197	1
III D 1	0.5	63.00	242	1
4	150	52.41	111	1

ments evenly distributed along the five test strips of an experimental point. The reflectance values obtained were relative to the reflectivity of a MgO-surface, taken as 100%. The latter was prepared in accordance with TAPPI Standard T 633 m-50. As a working standard, a nonglossy ceramic tile was used; its reflectivity, R_∞, was 82%. Specific scattering coefficient values obtainable from the average values of these measurements were calculated from the Kubelka-Munk equations given by Stenius (*12*, *13*).

The tensile testing was done on a recording tensile tester (Instron). The length of the test strip under tension was 4 in. and the straining rate was maintained at 0.2 in. per min. or 5% per min. This speed was considered the maximum rate of elongation at which accurate measurements of the weakest samples was still possible. From the stress–strain curves the break-

Table IV. Summary of Physical and Optical Data

Sample no.	Basis weight (ovendry), g.s.m.	Apparent density, g./cc.	Breaking length M.	Breaking length $\bar{\Delta}$, m.	Modulus of elasticity, dynes/cm.²	Modulus of elasticity, $\bar{\Delta} \times 10^{-10}$	Reflectivity, R_∞, %	Specific scattering coefficients, cm.²/g. S	S_0	$S_0 - S$
I A 1	65.1	0.202	730	20	0.25	0.02	49.06	378	380	2
2	65.4	0.295	1330	40	0.64	0.02	50.82	357		23
3	65.5	0.418	1930	40	1.10	0.03	49.68	345		35
4	62.1	0.536	3000	110	2.07	0.09	46.88	290		90
5	54.0	0.568	3130	130	2.06	0.16	45.97	246		134
I B 1	63.6	0.219	1280	50	0.46	0.03	50.67	396	400	4
2	64.0	0.305	1860	20	0.90	0.03	50.99	376		24
3	62.8	0.427	2600	50	1.46	0.04	50.84	365		35
4	62.6	0.522	3390	110	2.10	0.05	48.34	318		82
5	63.3	0.627	3950	60	2.70	0.06	43.99	218		182
I C 1	59.8	0.245	2130	110	0.66	0.04	53.07	416	420	4
2	61.1	0.358	2980	80	1.38	0.05	52.28	399		21
3	58.5	0.460	3790	170	2.06	0.05	51.31	364		56
4	60.3	0.582	5220	200	2.73	0.09	48.73	308		112
5	60.4	0.669	5980	210	3.53	0.09	44.15	216		204
I D 1	57.0	0.303	2950	90	0.98	0.02	53.30	483	485	2
2	58.2	0.438	4350	140	2.03	0.03	53.90	445		40
3	58.5	0.546	5120	260	2.81	0.10	51.62	377		108
4	58.1	0.636	5710	380	3.35	0.23	48.08	290		195
5	58.3	0.737	6620	430	4.20	0.09	43.70	210		275
II A 1	63.8	0.204	990	40	0.31	0.06	61.18	362	380	18
2	64.8	0.314	1570	90	0.73	0.04	61.47	358		22
3	63.4	0.448	2480	120	1.36	0.04	61.28	344		36
4	61.5	0.558	3600	100	2.11	0.12	59.16	291		89
5	54.4	0.626	4660	140	2.86	0.06	54.10	201		179
II B 1	61.0	0.243	2040	70	0.79	0.03	61.54	356	400	44
2	66.3	0.373	2910	120	1.45	0.11	60.82	347		53
3	64.2	0.503	4040	180	2.24	0.08	59.86	320		80
4	63.9	0.598	5050	130	3.02	0.16	57.37	259		141
5	63.7	0.671	6090	110	3.70	0.11	52.23	182		218
II C 1	63.9	0.306	3430	100	1.28	0.04	61.02	385	420	35
2	62.0	0.465	4690	200	2.28	0.05	60.22	348		72
3	60.7	0.564	5520	190	2.86	0.06	57.92	307		113
4	61.4	0.650	6490	170	3.63	0.06	55.11	238		182
5	60.5	0.705	7730	130	4.43	0.14	47.57	158		262
II D 1	62.0	0.405	5450	390	2.08	0.12	62.10	383	485	102
2	63.4	0.541	6220	210	2.80	0.15	59.69	329		156
3	64.0	0.624	7460	350	3.72	0.20	56.57	273		212
4	62.6	0.688	8090	70	4.17	0.08	53.87	215		270
5	63.8	0.748	8820	540	4.77	0.15	45.00	127		358
III A 1	68.4	0.301	2300	60	0.84	0.03	66.18	344	380	36
2	68.4	0.470	3650	90	1.97	0.05	65.51	313		67
3	68.0	0.571	4250	40	2.44	0.07	63.62	265		115
4	68.2	0.685	5570	180	3.14	0.05	60.40	197		193
III B 1	66.2	0.339	3570	100	1.25	0.03	66.70	336	400	64
2	65.5	0.495	4620	90	2.34	0.06	65.40	296		104
3	65.6	0.615	5640	220	3.18	0.08	63.21	254		146
4	65.1	0.705	6490	350	3.77	0.07	60.35	200		200
III C 1	66.0	0.387	4240	60	1.58	0.05	66.01	332	420	88
2	67.5	0.536	5220	90	2.53	0.12	64.15	292		128
3	65.5	0.645	6150	350	3.50	0.10	61.72	231		189
4	66.8	0.720	7110	230	4.05	0.10	58.27	177		243
III D 1	66.1	0.555	7300	220	2.98	0.13	63.00	242	485	143
2	64.9	0.670	8060	200	4.19	0.10	58.91	125		290
3	66.6	0.741	8470	140	4.46	0.11	57.16	159		326
4	67.6	0.797	9340	200	5.02	0.48	52.41	111		374

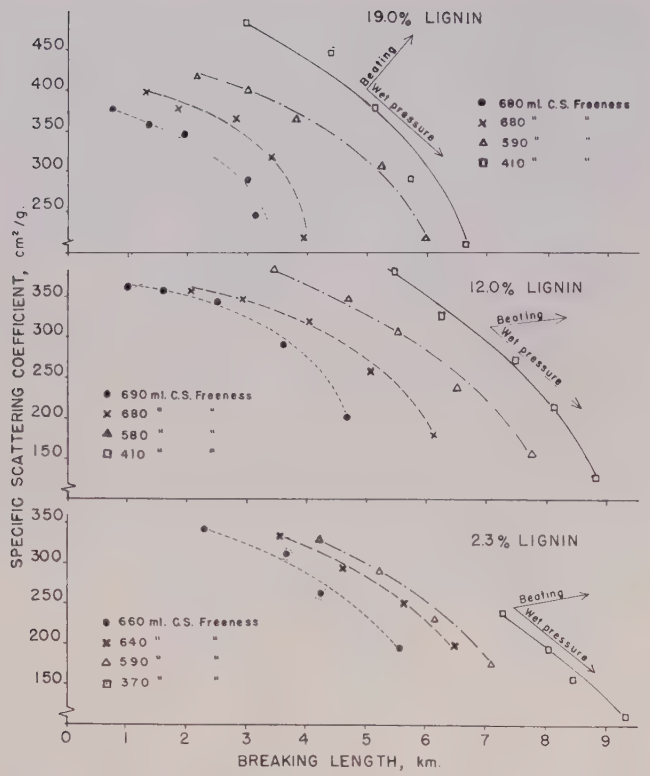

Fig. 1. The relationship between specific scattering coefficient and breaking length at various degrees of beating and delignification

ing length, elongation at rupture, modulus or elasticity and breaking energy were determined.

Statistical Treatment of Data

The main purpose of this work was to obtain specific data which could be utilized for the evaluation of the interfiber bonding characteristics of the above pulps. For the pertinent relationships between optical and mechanical properties, a statistical evaluation of the experimental results was made. As the mechanical properties were calculated individually for each test strip, the statistical confidence limits, of $\bar{\Delta}$, of the average test results were estimated. This was based on the standard deviation, s', and the Student's t-distribution for 90% confidence limit.

The statistical range of confidence values, $\bar{\Delta}R_\infty$ and $\bar{\Delta}R_0$ determined from 10 and 25 consecutive measurements for each experimental point, was 0.0006 absolute units. This estimation was also based on the t-distribution function at 90% confidence limit.

Values for the maximum variation of the resulting specific scattering coefficient, presented for the extreme wet pressure levels in Table III, have been calculated on the basis of the most unfavorable combination of conditions where $\bar{\Delta}R_\infty = -0.06\%$ and $\bar{\Delta}R_0 = +0.06\%$, i.e., in a case where both $\bar{\Delta}R$'s have the influence of shifting the scattering coefficient value in the same direction. This is an extreme condition that probably very seldom occurs.

EXPERIMENTAL RESULTS AND DISCUSSION

The mechanical and optical properties of the pulps produced by successive delignification, refining, and wet pressure are tabulated in Table IV. These pulps are referred to be the symbols shown in Table II. The wet pressures 0.5, 15, 50, 150, and 960 p.s.i. employed

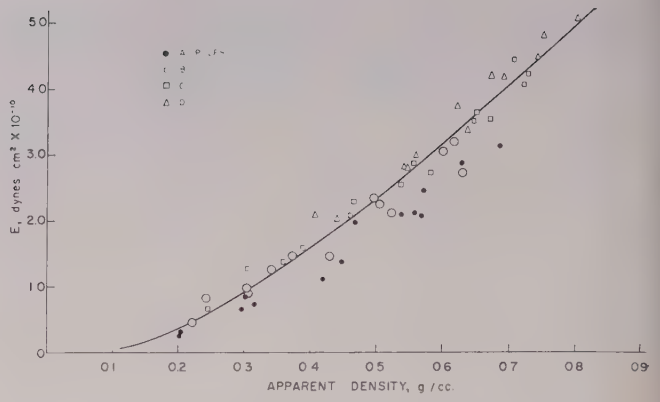

Fig. 2. The relationship between Young's modulus and apparent density for all the pulps used.

in sheetmaking have been assigned the numbers 1, 2, 3, 4, and 5, respectively. For example, pulp no. II C4 denoted 12% lignin, third ball-milling refining interval at 150 p.s.i. wet pressure. Scattering coefficients of the handsheets, S, expressed in sq. cm. per g. were plotted against the breaking length, as shown in Fig. 1 in accordance with the method of Thode and Ingmanson (*5*). A single value for S_0, the scattering power of unbonded fibers dried from water could not be obtained since, as Fig. 1 reveals, a distinct family of curves results rather than a common curve for all pulps, or for pulps at a particular lignin content. These findings along with Nordman's (*10*) and Swanson's (*11*) give reason to question the validity of the basic assumption of a constant dry fiber area available for bonding adopted by Ingmanson and Thode (*5*). The lack of a single S_0 value may also be due in part to the complexity of the breaking length index itself (*14*) when used as an extrapolation parameter to obtain fiber properties from sheet properties.

Two recent studies (*15*, *16*) have shown the close relationship that E, the elastic modulus of paper, bears to the paper density ρ. In fact, for a very large variety of paper pulps a linear relationship was obtained between E and ρ^2. These parameters, E and ρ, which are of a more fundamental nature than breaking length were used to study interfiber bonding.

Figure 2 shows the relationship between E and ρ for the data obtained in this investigation without any separation between the effects of beating and wet pressing. The same data gives a linear plot between E and ρ^2 with much less scatter. It can be seen that the majority of points fall on the same curve, the scatter occurring mostly for the slightly beaten and highly lignified samples. These results indicate that the presence of lignin in a well-beaten pulp does not interfere with the bonding and, as a consequence, the elastic modulus of paper. This relationship draws attention to the fact that while lignin in fibers reduces the ultimate sheet strength, the density of the fibrous material, irrespective of composition, determines the elastic modulus of paper. While the exact relationship between E and the ultimate strength of paper is not known, experience has shown that the elastic modulus strongly influences the ultimate sheet strength (*17*). In view of these findings, the parameters E and ρ were used in an attempt to find the relationship between interfiber bonding (bonded areas), Young's modulus and density through optical measurements.

Figures 3 and 4 show the relationship between the

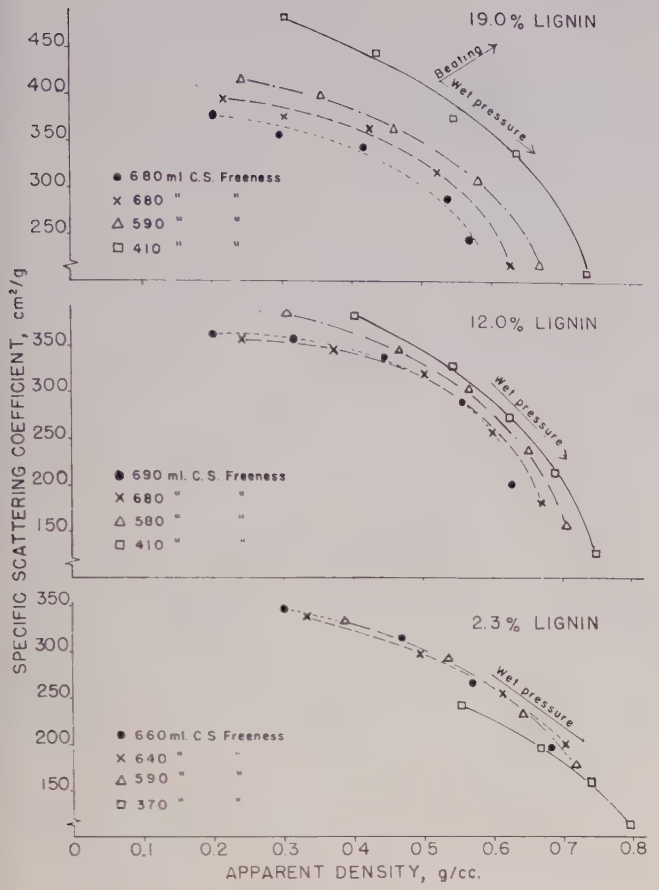

Fig. 3. The relationship between specific scattering coefficient and apparent density at various degrees of beating and delignification

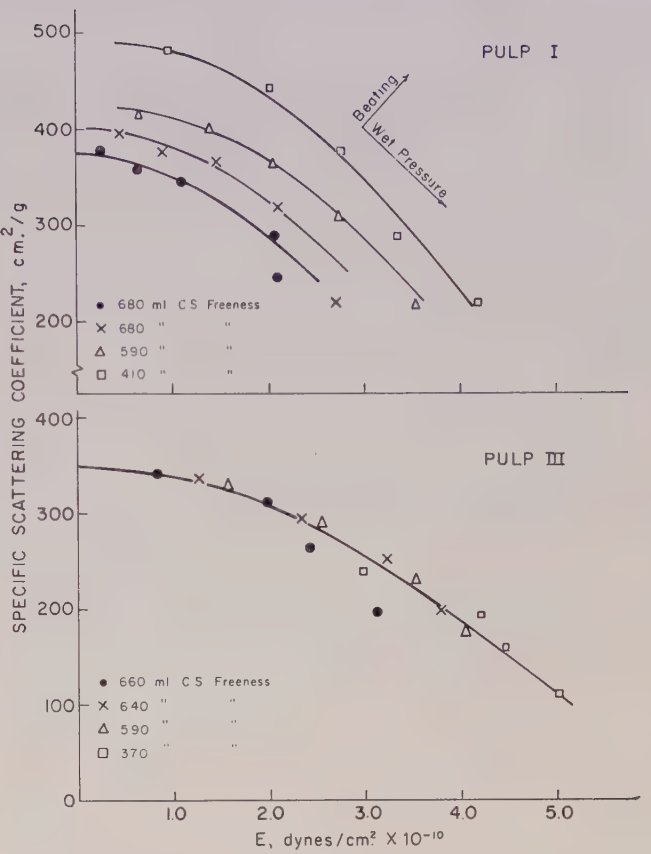

Fig. 4. The relationship between specific scattering coefficient and Young's modulus

scattering coefficients of the various pulps with ρ and E. Again in both instances, a series of curves similar to Fig. 1 are obtained. It is apparent from these results that the use of E and ρ in this manner does not permit one to obtain a single S_0 value for each pulp, especially for the pulps containing lignin. In the case of the curves S versus ρ extrapolation cannot be made to zero apparent density since a paper of zero apparent density has no physical meaning. The extrapolation, therefore, should be made to a limiting density value that corresponds to an assemblage of dry fibers in an unbonded state. Butanol-dried sheets can be used for this value. However, in view of the relationship between E and ρ it was felt that subsequent work should deal with only one experimental quantity, E, and consequently the density relationships were not used.

DETERMINATION OF S_0 AND BONDED AREAS

In the course of this investigation it was found that by plotting the scattering coefficient as a function of the modulus E, for the three pulps at constant freeness, a single curve was obtained at each freeness level. This is shown in Fig. 5 where it can be seen that reasonably accurate S_0 values can be obtained by extrapolation. The S_0 values obtained in this way are tabulated in Table IV.

Plotting the data in this way seems reasonable since pulps at equal freeness have the same wet external area. However, it is noteworthy that the scattering coefficients of the dried sheets are independent of the lignin content. This behavior may indicate that the external forces applied during sheet formation and developed during drying establish optical bonding, not only between cellulose and cellulose, but between cellulose and lignin as well.

The extrapolated S_0 values obtained from Fig. 5 increase with ball-mill refining. This is a result of the random rearrangement that the fibers and fibrils undergo in ball-mill refining.

Bonded areas were obtained from $S_0 - S$ and are plotted as a function of E in Fig. 6. Figure 6 shows that for pulps II and III the modulus develops rapidly at first and then decreases to a linear dependence on the bonded area. Pulp I, however, shows a somewhat different behavior. A more rapid initial increase of E with bonded area is observed than for pulps II and III, after which the same increase is maintained as for pulp II and III. This difference may be accounted for on the basis that this highly lignified pulp contains tubular fibers which have a higher bending modulus. This results in papers with higher moduli at the same bonded area than pulp II and III. At high bonded areas brought about by ball-mill refining the relationship between E and bonded area for pulp I is similar to pulp II and III. Evidently refining causes collapse of the fiber walls and the fiber contribution to the modulus is normal.

It may be discerned that for pulp I at very low bond areas refining results in higher moduli. However, for this pulp, and especially in this range, the experimental quantities of E and ρ on which the results are based are least accurate, and therefore any conclusion regarding the effect of refining is unwarranted.

The relationship shown in Fig. 6 is consistent with the relationship between E and ρ shown in Fig. 2,

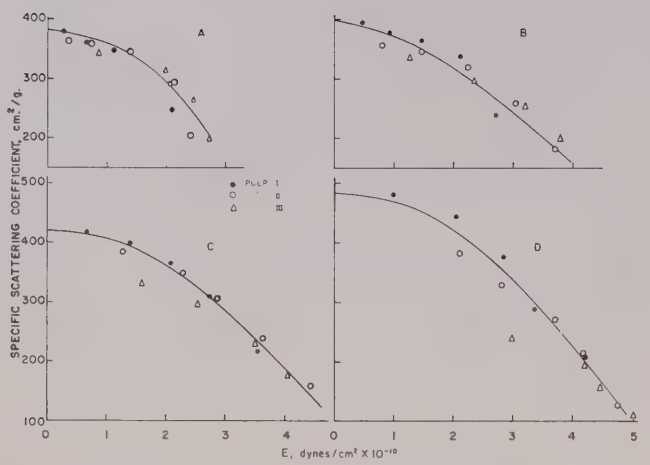

Fig. 5. The relationship between specific scattering coefficient and Young's modulus, plotted on the basis of equal refining

and indicates that the bonded area is closely related to the sheet density. Recently, Litt (*18*) has accounted for the relationship between E and ρ using a model for paper where the strain energy is stored in the fibers.

The results in Fig. 6 differ from those of Swanson and Steber (*11*). Using one S_0 value to determine the bonded area at all beating levels, they found a family of curves relating tensile strength to bonded areas. These results have been accounted for by assuming an increase in bond density in beating and delignification. Such an explanation has been presented previously (*11, 19*) especially by Nordman (*19*). He accounts for the differences found in the strength of pulps as due to differences in bond density.

At this point it is appropriate to consider the concept of bond density as it has been applied by Nordman and others to explain the variation in sheet strength.

Nordman has obtained values ranging from 2×10^5 to 10×10^5 erg per sq. cm. for the specific energy of separation of fiber-to-fiber bonds. He associated this energy with the interfiber hydrogen bonds in the bonded area. Since the optically bonded area is smaller than the surface area measured by nitrogen adsorption by a factor of 20, the bond density one calculates is 50 bonds

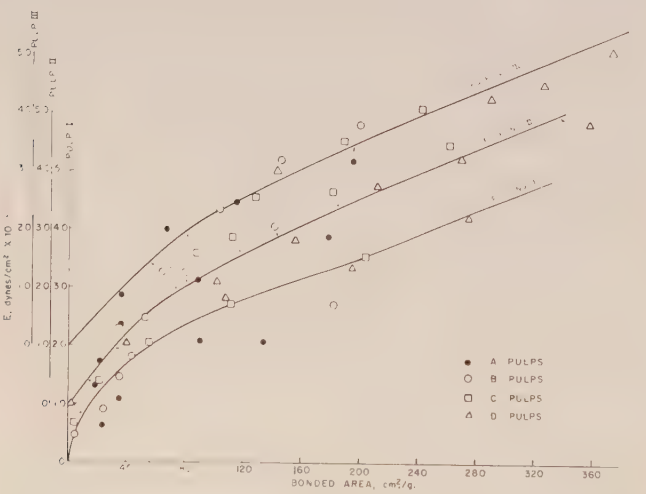

Fig. 6. The relationship between Young's modulus and bonded area for pulps containing different amounts of lignin.

Except for Pulp I at low bonded area, the three curves are identical

per glucose unit. It is obvious that this figure is entirely unreasonable. Evidently the energy stored on stretching is not stored only in the bonded area. In fact, a much more reasonable assumption is that most of the energy is stored in the fibers rather than in the bonded area, even though the bonded areas constitute points of stress concentration (*18*). It therefore follows that the concept of bond density to account for changes in sheet strength should be reexamined. It may very well be that the differences in ultimate sheet strength at equal bonded areas (nitrogen) rest in the properties of the fibers themselves and their arrangement.

CONCLUSIONS

The present study has shown that bonded areas may be obtained for high-yield pulps by optical measurements. This is based on determining the external water-dried surface area by extrapolating a plot of S versus E to E zero of a series of pulps at the same extent of refining. The bonded areas calculated were found to be a function of the Young's modulus of the handsheets. In view of the close relationship found between the density and modulus for a wide range of high yield pulps it would seem that the density of these papers determines the bonded area.

While it has been implicitly assumed in this investigation that the specific scattering coefficients are directly related to the free surface, as found with purified cellulose fibers (*8*), this assumption might not be valid for the type of pulps used in this study. Only when B.E.T. areas are obtained for high-yield pulps can the relationship in Fig. 6 acquire further significance. Such studies are at present under way.

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Chlorine Demand of Pulps

GUNTHER H. BALDAUF and BJORN O. LEHTO

Several types of unbleached pulp were evaluated in the laboratory under conditions paralleling mill operation. It was observed that chlorination proceeded in two distinct phases: complete consumption of chlorine at low levels of application, followed by reaction of a constant percentage of the chlorine applied in excess of the maximum amount which would react completely. The maximum amount fully consumed, was termed the "chlorine demand" of the pulp. It was considered to be a significant property of a pulp since it is a direct measure of the amount of chlorine to be applied in chlorination. Over the range investigated, a single linear correlation related "chlorine demand" and permanganate number for sulfite and kraft pulps. Separate correlations were found between "chlorine demand" and Roe chlorine number, the two values being about equal for sulfites, and "chlorine demand" significantly higher than Roe chlorine number for krafts. Tests of deinked pulps showed similar correlations, differing, however, in the consumption of any excess chlorine applied. The be havior of the deinked pulps was attributed to the presence of groundwood since it was duplicated closely by synthetic blends of bleached kraft and groundwood.

It is considered good bleaching practice to apply in the first step of a multistage bleaching process as much elemental chlorine as the pulp will absorb. Chlorine is probably the cheapest bleaching chemical that can be applied, in terms of final brightness gain; and, at the same time, if properly controlled, the use of chlorine results in a minimum of pulp degradation (*1*).

In view of the great importance of chlorination in bleaching, it is only natural that chlorine requirement be one of the first characteristics of interest in a pulp which is to be bleached, either in evaluating new pulps or as control tests for established pulps. For economic as well as quality considerations, it is desirable to do as much bleaching with chlorine as possible. On the other hand, using chlorine beyond the point where it completely reacts with the pulp is wasteful, and makes it difficult to contain the toxic and corrosive vapors in the vicinity of the pulp-washing equipment.

Tests commonly used to evaluate the chlorine requirement of an unbleached pulp are the permanganate or Kappa number, and the Roe chlorine number. The permanganate or Kappa numbers are actually a measurement of the amount of oxidizable material present in the pulp. Since chlorination is usually a combination of substitution and oxidation, such a measurement of oxidizable material would not be expected to be in direct relation to chlorine consumption. However, empirical correlations can be established between chlorine consumption under a given set of mill chlorination conditions and permanganate or Kappa numbers so that these tests are used satisfactorily for control purposes (*1*). On the other hand, when a correlation is lacking, as in the case of a new pulp or new chlorination conditions, it is difficult to interpret permanganate number, as far as chlorine consumption is concerned.

Roe chlorine number, which measures the amount of gaseous chlorine absorbed by a pulp sample under carefully standardized conditions, appears to parallel the actual chlorination process more closely. However, there still exist considerable differences as far as contact time, consistency, pH, etc., are concerned, so that a correlation curve with mill operation must be established just as in the case of permanganate number.

The reactions of chlorine with pulp have been reviewed and studied by Grangaard (*2*). By adding chlorine to pulp under carefully controlled conditions the total chlorine consumption, as well as its split into amounts consumed for oxidation and for substitution were measured. In order to get this complete picture of the chlorine reaction rather elaborate equipment was required, and a complete chemical analysis of the reaction mixture had to be made. Among other data, correlations were found, under laboratory conditions, between chlorine consumption and permanganate number when excess chlorine was applied to several pulps.

In pulp mill operation excess chlorine is avoided for the reasons outlined above. Hence, the experiments reported here were undertaken in an attempt to find a correlation between chlorine consumption under mill conditions and pulp tests. The procedures and equipment employed were kept as simple as possible consistent with obtaining reproducible results, in order to arrive at a method which could be carried out in a mill laboratory with the equipment normally on hand.

EXPERIMENTAL PROCEDURE

Chlorine was applied in the form of chlorine water, freshly prepared by bubbling chlorine into iron-free water. The strength of the solution was checked before each series of tests in accordance with TAPPI Standard T 611 m. The chlorine water was syphoned into a graduate for measurement, and then quickly poured into the reaction flask. A series of tests showed that as long as chlorine water concentration was held below 4 g.p.l. no appreciable amount of chlorine was flashed off during these manipulations. Hence, it was considered satisfactory to carry out the tests with dilute chlorine water without the need for special equipment for its transfer.

Ovendry samples of pulp (35 g.) were used for individual chlorinations. In the case of wet lap the appropriate amount of pulp was weighed out and placed into the reaction flask. Dry pulp samples were weighed, allowing for moisture, and then disintegrated in a blender. This was followed by filtration on Whatman no. 1 filter paper, and the filter cake weighed before placing into the reaction flask in order to determine the amount of water that had been added.

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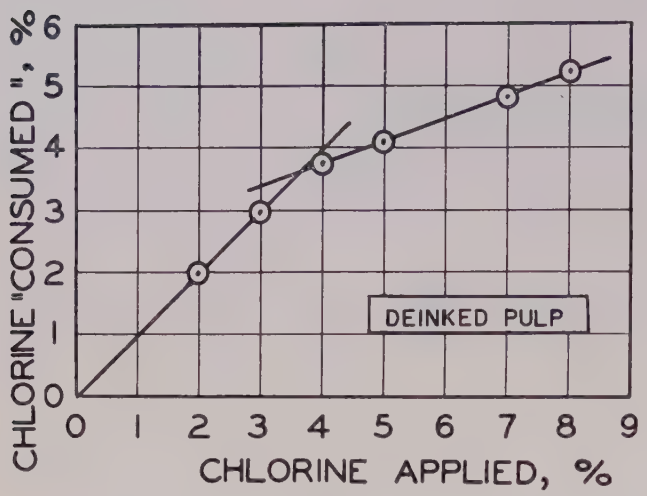

Fig. 1. Typical chlorine consumption curve

Chlorinations were carried out in 2-qt. Mason jars, under the following conditions:

Pulp sample, g.....35 g
Consistency, % ovendry.....3.5
Temperature, °F.....70
Chlorination time, min.....60

After placing the samples into the reaction flasks, the volumes of chlorine water needed for the desired chlorine applications were calculated. Amounts of water were then added to each flask so as to result in a final volume of 1000 ml. after the subsequent addition of the chlorine water. The pulp was dispersed by vigorous shaking, the chlorine water added, the reaction flask closed quickly and immediately shaken again. (A sheet of polyethylene was placed over the mouth of the Mason jar prior to closing, to prevent possible loss of chlorine by reaction with the jar lid.)

The reaction flask was shaken twice more during the first 5 min. and at 10 min. intervals thereafter. At the end of the reaction time, liquid was drained from the flask through a 100-mesh stainless steel wire and titrated for chlorine content in accordance with TAPPI Standard T 611 m.

Using this procedure chlorine application was limited to a maximum of 9%; i.e., if no dilution water was added to the pulp. At this maximum point pulp lap was placed in the flask and only chlorine water added.

Pulp blends were prepared by mixing the pulps in a dough mixer at about 10% consistency for at least 15 min. Permanganate number was determined in accordance with TAPPI Standard T 214 m. Roe chlorine number was determined in accordance with TAPPI Standard T 202 m.

RESULTS OF LABORATORY CHLORINATION

The results of each set of chlorinations on a given pulp specimen were plotted as per cent chlorine consumed versus per cent chlorine applied, both based on the ovendry weight of the pulp. Typical results are shown in Fig. 1.

As was to be expected, for relatively low chlorine applications all the chlorine was consumed and consequently the experimental points fall on a straight line of slope one. As the chemical application was increased, the amount consumed did not approach an

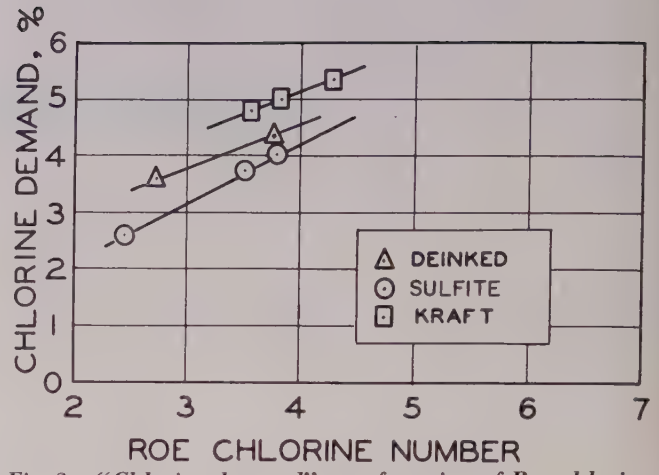

Fig. 2. "Chlorine demand" as a function of Roe chlorine number

asymptotic value; rather the data falls on a second straight line having a slope less than one.

It is quite apparent that the data can best be correlated by two straight lines. While there undoubtedly exists some curvature at the junction of the two lines, the experimental data, which usually included amounts of chlorine within ±0.25% of the transition point, did not reveal any. The points fell so close to the straight lines that it was deemed satisfactory to judge the location of the lines by eye rather than calculate the regression lines.

In the first experiments, chlorine was applied over a wide range. In every instance all the chlorine applied was consumed at low amounts of application. Hence, in later experiments, only sufficient data were obtained to define the second line, except for occasional checks to confirm the behavior of a pulp.

These findings parallel those shown by Grangaard for a balsam sulfite pulp chlorinated for 1 hr. (*2*). His data were actually extended into a higher range of chlorine application, where leveling off in chlorine consumption appeared to take place. Whereas in Fig. 3 of the reference cited, the correlation was shown with curvature between two straight lines, the data appeared to fit just as well to a correlation consisting of three straight lines, the first two corresponding to the range investigated here.

The intersection of the two straight lines of the chlorine consumption plot was termed the "chlorine demand" of the pulp. This is the value of interest to the pulp mill operator who wants all but a small frac-

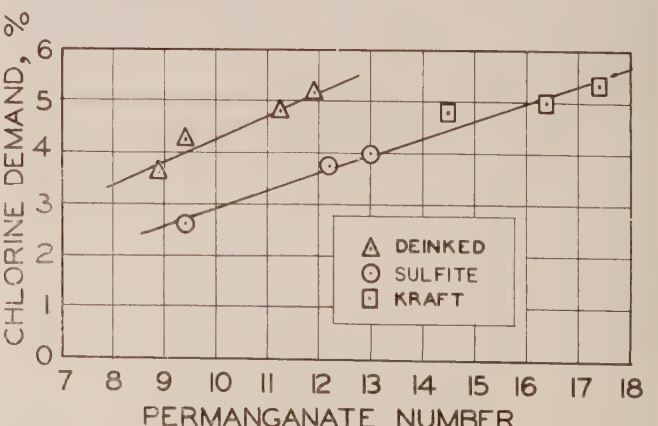

Fig. 3. "Chlorine demand" as a function of permanganate number

Table I. Summary of Test Results

Pulp	*Roe chlorine number*	*Permanganate number*	*"Chlorine demand"*	*Excess chlorine "consumed," %*
Finnish unbleached kraft	4.26	17.4	5.35	47
Canadian unbleached kraft	3.81	16.4	5.0	45
Canadian unbleached kraft	3.54	14.5	4.8	44
West Coast unbleached sulfite, hemlock	3.79	13.0	4.0	44
West Coast unbleached sulfite, hemlock/spruce	3.51	12.2	3.75	45
West Coast unbleached sulfite	2.46	9.4	2.6	44
Unbleached deinked pulps, 12% Groundwood)	2.74	8.9	3.6	36
16% Groundwood		11.25	4.8	63
18% Groundwood		11.9	5.2	53
15% Groundwood	3.82	9.4	4.25	46

tion of the chlorine applied to react with the pulp. Any additional amount of chlorine would result in unreacted chlorine, even though a fraction of the excess amount applied would still react. Table I lists the pulps tested together with the results of the tests.

CORRELATION WITH OTHER TESTS

The "chlorine demand," as determined by the intersection of the chlorine consumption lines, was compared with permanganate number and Roe chlorine number of the pulps. As shown in Figs. 2 and 3 good correlations were found.

The actual correlation appeared to depend on the pulp species. The "chlorine demand" when plotted against permanganate number followed a single correlation for the kraft and sulfite pulps; whereas two distinct correlations were noted when the "chlorine demand" was plotted against Roe chlorine number. For the sulfite pulps "chlorine demand" and Roe chlorine number agreed within experimental error, whereas "chlorine demand" was about 1% higher than Roe chlorine number for the kraft pulps. Hence, an erroneous conclusion would have been drawn in the case of the kraft pulps if chlorine requirement had been judged on the basis of Roe chlorine number.

The difference in the correlations was somewhat surprising. Since" chlorine demand" and chlorine number determinations are basically similar procedures, differing primarily in conditions of chlorine application, it had been expected that a single correlation valid for the different pulps would be found. On the other hand, since permanganate number is a measure of oxidizable matter present and chlorination results in both oxidation and substitution, the single correlation which was found applicable for both kraft and sulfite was unexpected.

No general significance should be attached to the specific correlations obtained since the "chlorine demand" value is a function of the test conditions which were set up to parallel a particular set of mill operating conditions. Thus, if conditions had been changed to correspond to other mill conditions, the correlations might have been changed even though their general appearance would be expected to remain the same.

Deinked pulps appeared to fall into a category different from krafts and sulfites. When compared at equal permanganate number, their chlorine demand was higher than either sulfite of kraft pulps. At equal Roe chlorine number, their chlorine demand is intermediate between the kraft and sulfite pulps. As discussed below, deinked pulps also differed from the virgin pulps in the consumption of the chlorine applied in excess of the chlorine demand.

CONSUMPTION OF EXCESS CHLORINE

The fact that chlorine consumed plotted against chlorine applied falls on a straight line above "chlorine demand," means that a constant percentage of the excess chlorine applied is consumed. For all the chemical pulps tested the "percentage consumed" is the same, as shown in Table I. This similarity in behavior of different pulps was rather surprising. Deinked pulps again showed unique behavior, varying widely in consumption of the excess chlorine applied.

The "percentage chlorine" consumed, as calculated from the slope of chlorine consumption plots such as Fig. 1, requires some correction if it is desired to know the exact amount of excess chlorine that has reacted with the pulp. In view of the experimental procedure employed, any chlorine in the vapor phase of the reaction vessel would be considered consumed chlorine. A series of blank determinations showed that the liquid phase actually contained only about 90% of the chlorine present in the system. Thus, for example, for virgin pulps the actual unreacted chlorine was $55/0.9 = 60\%$; or 40% of the excess chlorine had reacted.

As far as the determination of the "chlorine demand" is concerned, the nature of the reaction of the excess chlorine, or the loss of chlorine to the vapor phase, is actually inconsequential as long as test conditions are maintained constant for the series of tests so as to produce a straight-line correlation. While the use of different test equipment could result in a change of slope of the second line, the intercept of the two lines would not be affected. In fact "chlorine demand" could be determined without experimental points on the second line by making a series of tests in the range of

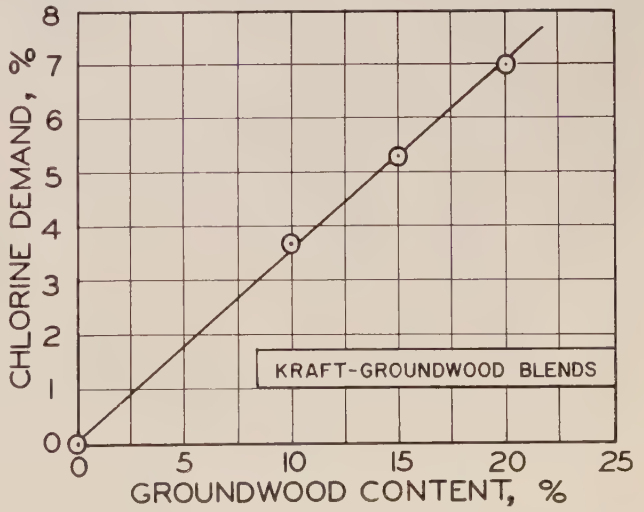

Fig. 4. "Chlorine demand" as a function of groundwood content

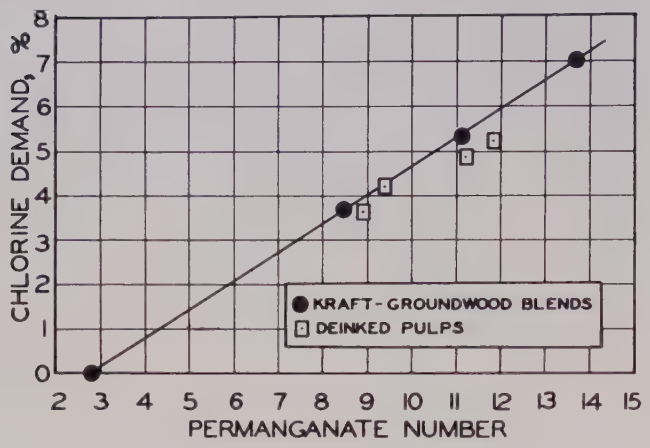

Fig. 5. "Chlorine demand" as a function of permanganate number

100% chlorine consumption, increasing the chlorine application until the "chlorine demand" is reached. At this point all the chlorine is no longer consumed. In practice, however, this would require many test points closely spaced, and it is obviously simpler and more accurate to determine "chlorine demand" by the intercept method proposed here.

DEINKED PULPS

Deinked pulps of the type tested here are, basically, mixtures of bleached chemical pulps and groundwood. In addition there are present relatively small amounts of semibleached and unbleached pulps, as well as dyes, pigments, ink particles, etc.

To determine whether the presence of groundwood causes the difference in behavior of deinked pulp as compared to virgin chemical pulps, mixtures of known groundwood content were tested. The mixtures were prepared by blending a 75 G.E. brightness softwood kraft (chlorine-caustic-hypochlorite bleached) with virgin groundwood.

Figure 4 shows the "chlorine demand" of these pulps as a function of groundwood content. The linear relationship, as well as the zero "chlorine demand" of the chemical pulp, indicates that the chlorine usage is entirely due to the groundwood. (By extrapolation the "chlorine demand" of the groundwood was 35%, though, as stated earlier, values in excess of 9% could not be measured directly by this technique.) Figure 5

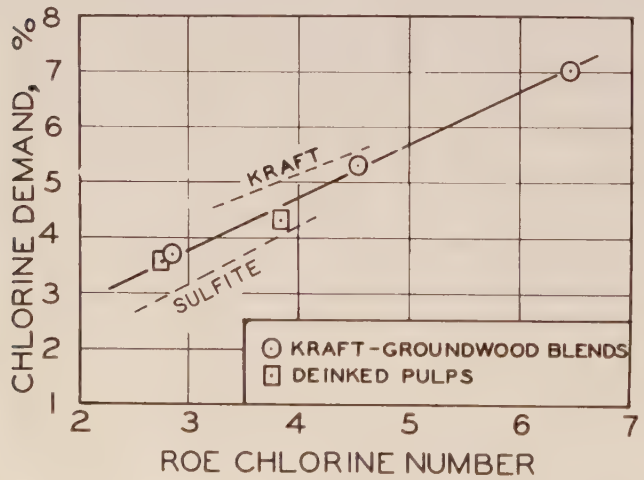

Fig. 6. "Chlorine demand" as a function of Roe chlorine number

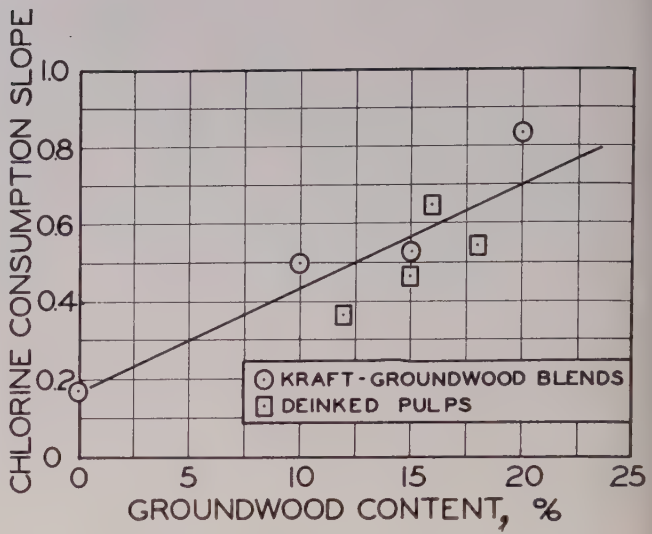

Fig. 7. Chlorine consumption slope as a function of groundwood content

shows the "chlorine demand" as a function of permanganate number; also a straight-line correlation.

Also shown in Fig. 5 are the points for deinked pulps, and it is apparent that these points fall in line with those for kraft-groundwood blends. As discussed earlier, deinked pulps did not fall in line with unbleached kraft or sulfite pulps, Fig. 3.

A similar plot for Roe chlorine numbers is shown in Fig. 6. It is apparent that the deinked pulps and the kraft-groundwood blends follow the same correlation which lies between those for kraft and sulfite pulps, as established in Fig. 2.

A plot of the slope of the chlorine consumption curves above "chlorine demand" for both the deinked pulps and the kraft-groundwood blends as a function of groundwood content is shown in Fig. 7. It is apparent that the slope increases with groundwood content and that the same general correlation applies for the two pulp systems.

From these observations it was concluded that the unique behavior of deinked pulps as compared to the virgin unbleached pulps was due to the presence of groundwood.

APPLICATION TO ROUTINE TESTING

The straight-line correlations, together with the constancy of the consumption of the excess chlorine, means that the "chlorine demand" could be calculated from the results of a single chlorine consumption determination at a chlorine application above "chlorine demand." This greatly simplifies the procedure if a large number of samples are to be evaluated. Derivation of the equation is shown in the Appendix. For example, at 45% excess chlorine consumption the per cent "chlorine demand," CD, is given by:

$$\%CD = 1.82Y - 0.82X \qquad (1)$$

where

X = chlorine applied, %
Y = chlorine consumed, %, at some point in excess of "chlorine demand"

For maximum accuracy it is desirable to apply about 0.5% chlorine, based on pulp, in excess of "chlorine demand" when making such single-point measurements.

This minimizes any errors in the extrapolation due to variations in the excess chlorine consumption.

This simplified procedure can be applied only to virgin chemical pulps since, as discussed above, the slope of the chlorine consumption curve is not constant for pulps containing groundwood.

SUMMARY

The reaction of unbleached pulps with chlorine under conditions paralleling mill operation was studied. It was found that the consumption of chlorine takes place in two phases: In the first phase, that of a low chlorine application, all the chlorine applied is consumed. As chlorine application is increased, a second phase is reached in which a constant percentage of the excess chlorine applied reacts.

The per cent chlorine applied beyond which the pulp would not completely consume additional chlorine was termed the "chlorine demand" of the pulp. This is considered the most direct method available for judging the chemical consumption of a pulp in chlorination under production conditions. It is shown how this value could be determined by a single laboratory chlorination.

"Chlorine demand" can be correlated with Roe chlorine number and permanganate number, although the specific correlations depends on the type of pulp. Deinked pulps differ from virgin pulps in their behavior, because of the presence of groundwood.

APPENDIX

CALCULATION OF "CHLORINE DEMAND"

Let x = % chlorine applied and y = % chlorine consumed.

Below "chlorine demand" $y = x$ (2)

Above "chlorine demand" $y = a + bx$ (3)

"chlorine demand" is the value of x and y found by the solution of simultaneous equations (2) and (3).

If b, the slope of the line above the "chlorine demand," is known, "chlorine demand" can be calculated from a single experimental point; since such a point will define the straight line (3).

Let the experimental values for per cent chlorine applied and per cent chlorine consumed be X and Y, respectively. Then equation (3) can be solved to give:

$$a = Y - bX \quad (4)$$

Substituting this value of a in equation (3), and solving the simultaneous equations (2) and (3), we obtain:

$$\text{"Chlorine demand"} = \frac{Y - bX}{1 - b} \quad (5)$$

For example, at 45% excess chlorine consumption $b = 0.45$ and equation (5) becomes:

$$\text{"Chlorine demand"} = 1.82\ Y - 0.82\ X$$

Hence, a single experiment which gives the values of Y and X will make possible the calculation of "chlorine demand."

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Biological Deterioration of Pulpwood and Pulp Chips During Storage

RALPH M. LINDGREN and WALLACE E. ESLYN

The amount and causes of microbiological deterioration of pulpwood and pulp chips during storage are compared, with particular emphasis on southern pine and hardwoods. Damage to chips is greatest in the outer few feet of the sides of piles and develops faster in such hardwoods as gum and oak than in pine. General but not intense nonfungus discoloration of chips occurs in pile interiors. Overall damage appears to be less in pine, possibly somewhat greater in gum, and probably no more in oak chips than usually occurs in stored rough pulpwood of similar species. Microfungi that produce a condition known as soft-rot are an important cause of deterioration in all chip piles. Wood-decaying Basidiomycetes, that are the primary destructive agents in pulpwood, also are important in hardwood piles. Soft-rot fungi characteristically are found in the highly cellulosic secondary walls of the wood fibers, forming spirally oriented cavities which often are rhomboid in shape. These fungi utilize the cellulose of wood principally, attack hardwoods much more readily than softwoods, and can develop in wood exposed to environments that are unfavorable for growth of the typical wood-decay fungi.

Ralph M. Lindgren, Chief Division of Wood Preservation, and Wallace E. Eslyn, Pathologist, Forest Products Laboratory, maintained at Madison, Wis., in cooperation with the University of Wisconsin, Forest Service U. S. Department of Agriculture.

The possibility of storing wood for pulping in the form of chips has received increasing consideration in recent years. This interest has arisen from the need to improve operating techniques in the general handling of stored wood, increase the volume of wood that can be held on a given acreage of land, and reduce the amount and effects of wood deterioration during outside storage. Encouraging results at a number of western mills have focused attention on chip storage as a means of meeting these objectives. Some of these mills have practiced such storage since 1950, and now depend heavily on by-product wood that is received in chip form from lumber, veneer, and other wood-processing plants.

The magnitude of present losses due to biological deterioration of stored pulpwood is difficult to assess (*24*). Various estimates have been presented in the literature and at meetings but, for several reasons, consistency has not been one of their virtues. One of the early estimates, made by a Government agency, in 1924, was that 10% of the pulpwood cut at that time was lost as a result of decay (*7*). Although the current overall damage is far below this percentage, it probably exceeds the

earlier annual monetary loss because of the great expansion in the paper industry and the higher cost of wood. With southern pine pulpwood, for instance, recent estimates indicate that yearly losses in wood yield alone range from 2 to 4 million dollars, even though extended storage is uncommon. Similar or possibly greater losses are not unlikely for some other woods that are moved much less rapidly than southern pine. Therefore, any new systems of wood handling, as for wood in chip form, could be important, if only for reducing deterioration during storage periods.

This paper summarizes available information on the causes, effects, and factors that influence biological deterioration of pulpwood as compared to wood chips stored in piles. Much of the information on chip storage was developed during recent research conducted in

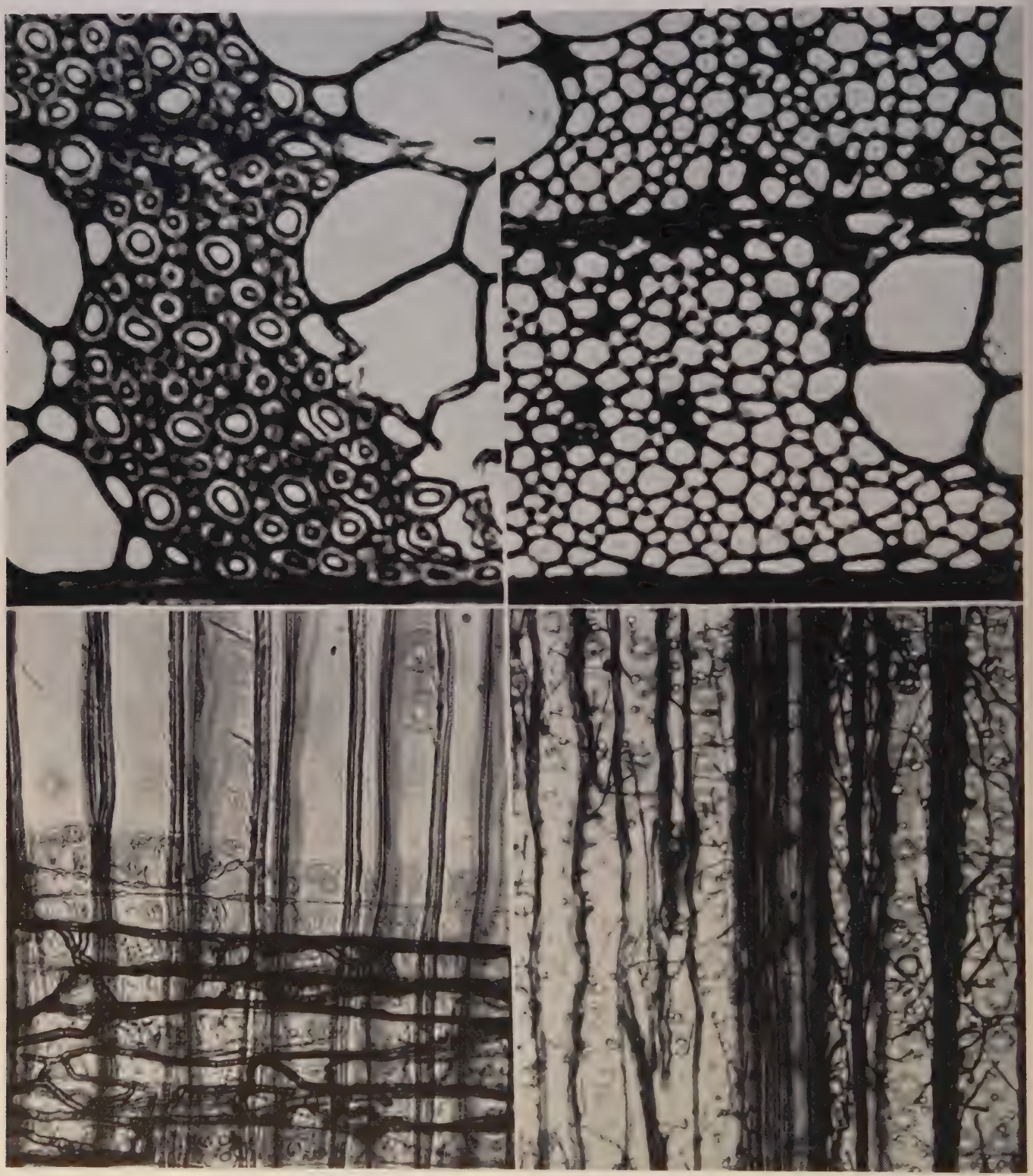

Fig. 1. Illustrations of type and location of attack by wood-decay and staining fungi

Cross-sections showing normal fibers in elm (upper left) as compared to greatly thinned fiber walls caused by a white-rot fungus (upper right). Longitudinal section of pine illustrating concentration of staining fungi in the wood ray cells (lower left). Longitudinal section of pine showing bore holes in tracheid walls caused by a brown-rot fungus (lower right).

cooperation with the Brunswick Pulp and Paper Co. St. Regis Paper Co. and the Southeastern Forest Experiment Station of the Forest Service, U. S. A.

DETERIORATION OF PULPWOOD

Shema (*24*), in 1955, published a detailed review of literature on the microbiology of pulpwood. The present discussion on deterioration of pulpwood covers some data released since that time, but primarily summarizes certain aspects of the problem for comparison with data presented later on the microbiology of wood chips stored in piles.

Causal Organisms

Deterioration of pulpwood is caused principally by fungi of two general types: (1) staining and molding organisms that usually are members of the Ascomycetes or Fungi Imperfecti, and (2) wood-decaying organisms that largely are higher fungi of the Basidiomycete group. Both types of organisms require a minimum of about 18% moisture in the wood, wet basis, to initiate attack. At the other extreme, wood moisture content levels that approach 50%, wet basis, become progressively less favorable for fungus growth. Insects usually are the direct cause of only minor destruction of wood in storage. However, they carry a variety of fungi into the wood and, therefore, lead to earlier and more rapid fungus deterioration than would otherwide occur, particularly in rough wood.

Staining and molding fungi are important in pulpwood primarily because they discolor wood. Their attack is concentrated in sapwood and in nonfibrous cells that are of little significance in supplying cellulose for pulp (Fig. 1). Consequently, their effect on reduction of strength of wood usually is minor. Among the most common organisms of this type in pulpwood are species of *Ceratocystis, Graphium, Trichoderma, Penicillium, Aspergillus, Hormonema, Hormodendrum,* and *Gliocladium.*

Wood-decaying fungi attack both cellulose and lignin and may greatly reduce the yield and quality of pulp obtained from the wood. They are classified into two general but often not well-defined types—white-rots and brown-rots—based partly on their effects on color of the wood. White-rotting fungi attack both cellulose and lignin indiscriminately and, therefore, may eventually cause almost complete destruction of the wood. This is evident from the progressive thinning of fiber walls that is associated with their attack (Fig. 1). The white-rots are likely to be more common as a storage decay in hardwoods than in softwoods. Brown-rotting fungi attack cellulose in preference to lignin and also lower pH appreciably, with an accompanying increase in the alkali solubility of the wood. Much of the storage decay in softwoods, but not most hardwoods, is caused by organisms of this type. Microscopically, their attack of wood is characterized more by the production of bore holes through fiber walls than by a general thinning of the walls (Fig. 1). For given stages of decay, as indicated by losses in specific gravity, greater reductions in pulp yield and quality usually are shown by brown than by white rotted wood (*19*). Since the infected wood is more friable, larger losses from wood with brown-rot also can be expected in barking, chipping and general wood-room operations.

The prevalence of specific decay fungi in stored pulpwood varies with the species of wood and, to some extent with the region and conditions of storage. The principal fungus in southern and northern pines is *Peniophora gigantea,* which causes an intermediate type of decay (*14, 18*). Pine pulpwood stored for long periods is likely to be attacked also by such brown-rot fungi as *Lenzites saeparia.* Among the most common fungi on other softwood species are *Polyporus abietinus, P. volvatus, P. annosus, Fomes pinicola, F. roseus, Trametes serialis,* and *Stereum sanguinolentum,* most of which cause brown-rots. In hardwood pulpwood, the prominent species include *P. hirsutus, P. versicolor, P. adustus, P. gilvus, Daedalea confragosa, D. quercina,* and *Stereum purpureum,* all of which are white-rot fungi.

Effect on Wood Density

Decay has little effect on volume of the pulpwood, so that the extent to which decay reduces density is a reasonably good criterion of loss of pulp yield per cord of wood prior to pulping. Unfortunately, the carefully conducted studies that are needed to measure specific gravity changes during storage have been very few. It is not surprising, therefore, that reports in the literature on the amount of deterioration to be expected often seem inconsistent. One reason for this variability has been that reliable information on the length and season of storage frequently was lacking. A common, early discrepancy was to recognize storage at the mill only, thereby disregarding sometimes lengthy periods before the wood arrived at the mill. Another source of confusion has been to report storage losses on pulpwood cut from dead timber or trees with heart rot. Such material presents so many complications in evaluating storage losses that inconsistent reports are almost inevitable.

In the southern pine region, losses in specific gravity of stored wood due to decay have been the subject of a number of studies. The data indicate that losses in rough pine stored in summer (April 15 to October 15) range from 2 to 4% in 2 months, 5 to 8% in 4 months, and 7 to 10% in 6 months (*14*). During winter storage (October 15 to April 15), reductions due to decay usually are about one-third those in the summer. For a full year of storage, decreases in specific gravity of 11 to 15% can be expected. Peeled pine stored in large separated ricks generally undergoes losses thare are about one half those in rough pine, with the most rapid reductions usually occurring during the first 3 to 4 months. Deterioration of peeled wood tends to be more variable than that of rough pulpwood, probably because it is influenced more by abnormally wet or dry weather. Losses generally are lower in peeled wood stored in winter than in summer, but abnormal weather sometimes makes the difference slight.

The storage of southern hardwoods has received much less investigative attention than that of pine. Based on one study in Georgia (*8*) and unpublished data collected in Mississippi, density losses due to decay of rough gum are somewhat higher than those indicated for southern pine. Although small oak pulpwood, comprised largely of sapwood, appears to deteriorate about as fast as gum, overall losses for red oak usually are lower because of a larger percentage of more resistant heartwood. No data have been reported for other southern hardwood species, and the present indicatory information on gum and oak needs verification.

In other regions, available information on decay-induced losses in density of stored wood is based, with a few exceptions, on observations and experience rather than carefully conducted studies. Deterioration in the Lake States and Northeast is limited largely to about 5 months during warm weather. Storage of rough pulpwood of such species as balsam fir and aspen apparently results in some of the largest decay losses. For example, unpublished data on pulpwood stored 4 years showed density losses of 25 to 30% for aspen and balsam fir, which appreciably exceeded those for jack pine and spruce. In one test of rough jack pine stored about 2 years (*19*), specific gravity reductions were approximately 5% after 1 year and 9% after 2 years. Peeled pulpwood in these regions, if handled properly, apparently can be stored for periods as long as 2 years without serious decay damage. Sap stain may introduce a discoloring problem at times but has little effect on specific gravity of the peeled wood.

In the Northwest, hemlock is considered to deteriorate at a somewhat faster rate than Douglas-fir. Even with hemlock, however, losses in stored rough pulpwood cut from living trees may be only 4% or less after 2 years of storage (*27*). In the same study, hemlock pulpwood cut from infected dead timber showed losses of 13%. Apparently, 1 year of storage is comparatively safe for such species as hemlock, Douglas-fir, and Engelmann spruce, and losses even after 2 years are moderate for wood cut from live timber. One factor that undoubtedly contributes to slow deterioration of such western woods is the large size and high heartwood content of the pulpwood. However, the use of heart-rotted and dead timber for pulpwood is not uncommon, which leads to increased decay losses during storage. Although evidence on red alder is not available, indications are that it would be subject to greater reductions in density during storage than most other western woods.

Effect on Pulp Yield and Quality

There is fairly extensive literature on the effects of storage decay on the yield and quality of pulp (*24*). In many cases, however, needed data are lacking on results with sound wood as a control, the length and season of storage, and the amount and type of decay. Consequently, information available is not as quantitative as would be desirable for a clear-cut evaluation of storage losses in relation to pulp yield and quality. This discussion will be limited to the general effects of deterioration during storage, as revealed by the various pulping trials.

It is almost generally agreed that pulp from wood with only blue stain infection has not been significantly reduced in yield or strength properties. However, discolored chips tend to darken pulps, increase dirt content, and require more bleach than chips from uninfected wood (*4*). Blue stain infection only, since it is closely followed by decay, usually indicates that the pulpwood has been stored for a short time.

The effect of decay on yields and quality of pulp tends to increase progressively with the amount and stage of decay (*3, 8, 12, 13, 17, 18, 19, 25*). Pulp yields on a dry wood basis often show little or no reduction for chips with relatively light decay, although the reports in literature are variable on this point. For chips from heavily decayed pulpwood, however, losses in yield may range from below 10 to 20% or higher. Prior to pulping badly decayed material, additional losses in wood volume of 10% or more may occur in chipping and other woodroom operations.

Losses in strength of pulp seem to follow the same general pattern as those for the effect of decay on yield. Depending on the severity of decay, reductions in strength properties may range from below 10 to 30% or more. Tensile strength apparently is among the properties that are least affected by decay. In southern pine, effects on pulp strength were reported to be measurable when the chips came from wood that had decreased 3% or more in density due to decay (*15*). For pulps from wood reduced 7 to 14% in density, reductions of about 25% in tear resistance and bursting strength and 75% in folding endurance were obtained (*3, 17*). In hardwoods, lower tearing strength appears to be one of the principal effects of decay. Losses in this property of 2.0 and 4.5% per month for pulps from stored oak and gum, respectively, have been reported (*8*).

Other effects of decay on pulp quality are to darken the pulp, cause more dirt and shives, and increase the consumption of chemicals. The importance of these effects varies with different pulping processes. Higher bleach requirements are a more important factor in groundwood and sulfite than in sulfate pulping. However, the higher alkali consumption by pulps from decayed wood is of particular significance in the sulfate process.

Factors Important in Reducing Damage

The principal methods of reducing fungus damage in rough and peeled pulpwood have been to store only as long as is necessary and to pulp the oldest wood first. Peeling has been a safeguard for wood to be stored for long periods. Best results from peeling require quick removal of the bark after cutting and storage of the peeled wood in well-ventilated ricks.

Other factors that are important in reducing storage losses have been disclosed by various studies. These are as follows:

Time of Storage. Winter storage invariably results in the lowest losses from decay and discoloring fungi. Even in the South, the rate of attack by these organisms in winter is about one third that in summer. Optimum temperature conditions for the fungi occur at 70 to 95°F. Their growth at even such temperatures as 60°F. is reduced to one-half or less of that at the more favorable temperatures. At temperatures of 40°F. or less, their activity practically ceases.

Size of Pulpwood. For rough pulpwood, bolts of large diameter and long length should be favored for storage (*15*). Rough pulpwood of long length leads to less damage because infections enter the end first; also, lower moisture-content levels favorable for fungus growth are reached earlier toward the ends than the middle of pulpwood sticks. As to diameter, unpublished data on southern pine indicate that density loss due to decay of 10- to 12-in. wood may be two thirds or less that of 5- to 6-in. wood. Apparently, high moisture content levels that retard fungus growth are maintained much longer in the larger wood. Such wood also tends to have a higher percentage of the more resistant heartwood.

For peeled pulpwood, practices that lead to less damage are the reverse of those for rough wood. Thus, the selection of pulpwood of short length and small diameter, and the splitting of large wood, reduce the hazard of damage. In studies on southern pine, losses in peeled wood of 5 to 6 in. diameter were about one-half those in 10- to 12-in. wood. The purpose of peeling pulpwood for storage is to hasten drying to wood moisture content levels that are too low for fungus growth. This purpose is attained more rapidly as diameter and length of wood decrease.

Method of Piling. For rough pulpwood, storing in large unaerated piles maintains high moisture contents that retard fungus attack (*15*). Lower interior temperatures in such piles, particularly in summer, also tend to slow deterioration. Much of the early literature stressed ventilation of stored rough pulpwood in the mistaken belief that drying would proceed fast enough to reduce decay.

The amount of decay in peeled wood is inversely related to the rate of drying that results from the piling method used. Therefore, the storage method should provide conditions as open and well-ventilated as possible, if losses are to be kept at a minimum.

Use of Water. Of all methods for rough pulpwood, storage in water insures the greatest control of deterioration over extended periods (*3*). The wood preferably should be freshly cut at the time of storage and kept completely submerged. Water sprays that keep the wood wet during the warm seasons of the year also are highly effective in reducing damage (*27*). The earlier use of sprays at pulp and saw mills was largely for fire prevention, but the method is now widely used to prevent deterioration in stored logs.

Treatment with Chemicals. Fungicidal and insecticidal treatments to reduce damage in rough pulpwood have shown promise but have not been widely used (*16, 18*). A great drawback to wider use of such treatments is the need to apply the chemicals almost immediately after cutting the wood. The mechanics and cost of treating also are requirements that are difficult for most mills to meet. For peeled wood, drying usually proceeds fast enough to keep decay losses low, and absence of bark alone greatly reduces insect attack. Therefore, chemical treatments are considered less necessary and practicable for peeled than for rough wood.

PAST REPORTS ON DETERIORATION OF STORED CHIPS

General

There have been an increasing number of recent articles on the outdoor storage of pulp chips in piles, with particular reference to its use at western mills and its practicability in general. Douglas-fir is reported to be the main species stored in chip form at western mills, but other species include hemlock, true firs, cedar, and pine (*2*). All of these woods apparently have shown little deterioration within 2 years, and Douglas-fir and cedar chips have been stored as long as 3 years without high losses. A few similar observations on limited trials of outside storage of southern pine also have been under way (*10, 11*). These have indicated that pine chips can be stored at least 4 months with little fungus deterioration except molding and staining in the outer 2 or 3 ft. of the pile. Other observations were that moisture content of the chips and temperatures tended to increase during the first few months, particularly in the interior of piles. Pulping trials usually showed no changes, or only minor ones, in yield or quality of pulp, but the reports have not been entirely consistent on this point.

The few reported studies on chip storage have been, with one exception, exploratory in type, involving rather small and usually uncompacted piles. One such study (*26*) in the West showed that red alder decayed much more rapidly than Douglas-fir in small piles containing mixtures of the two chips. Decay of alder decreased with an increase in the proportion of Douglas-fir chips in the pile. The only fungi isolated were an unidentified wood-rotting Basidiomycete and *Graphium* from alder, and a different *Graphium* and *Trichoderma* from the Douglas-fir chips.

The remaining exploratory studies concern southern pine and hardwood chips. The one on pine (*9*) involved several piles, the smallest of which showed only small losses in density of chips and no loss in yield after 10 months. From a larger pile stored 12 months, indications were that yield was unchanged but rejects were doubled, moisture content of the chips increased to 60% except in the pile center, and pulp strength was reduced 15 to 35% for tear and 15 to 18% for burst.

The second study (*5*) covered $5^1/_2$ months of storage of gum and oak chips in rather small, loosely constructed separate piles. Both piles showed about a 10% increase, on the wet-weight basis, in moisture in the outer shell but only a slight increase for gum and some drying of oak chips in the interior of the pile. Temperatures in both piles increased rather markedly, particularly in the interior. Density of the wood was reduced about 1.4% per month for the oak and 2.5% for the gum chips. Losses of pulp strength amounted to 2% per month for the oak and about 3% for the gum chips, and represented a loss of tearing resistance. No loss in yield based on wood charged to the digester was obtained for both piles. Likewise, the permanganate number and proportion of screen rejects were not influenced by storage. A number of staining and molding fungi, but no wood-rooting Basidiomycetes, were identified from chips in both piles.

RECENT DATA ON DETERIORATION OF STORED CHIPS

During 1959 and 1960, the Forest Products Laboratory cooperated in studies of outside pulp-chip storage in the South, as mentioned earlier. Five piles were involved, two of slash pine, one of oak, and two of gum, one of which was periodically saturated with water. The periods represented were 5 to 6 months of summer storage at either Fargo, Ga., or Brunswick, Ga., for the gum, oak, and one of the pine piles, and 1 year of storage for the remaining pine pile. The piles varied somewhat in size but contained up to about 100 units of chips that were compacted with a large tractor. The results of one of these studies have appeared in print (*20*), and detailed publications of the remaining studies are being prepared by the cooperators. The present paper will summarize some of the principal findings for all studies, including the one recently published, with particular emphasis on the organisms responsible for

Fig. 2. Three general types of chip condition in storage piles of southern pine

General brown nonfungus discoloration but no visible infection (lower left); dark stain which eventually led to surface softening of the chips, caused by soft-rot fungi (lower right) typical decay by Basidiomycete fungus as indicated by bleached areas which were greatly softened (upper). A fourth type, mold and light stain, is not shown.

chip deterioration, their effects on wood, and how deterioration of chips compared with that of pulpwood.

General Results

Average moisture content of the chips in all piles increased 10 to 15%, wet-weight basis, during 6 to 12 months of storage. For the first 2 to 3 months, highest moisture-content values usually were shown by chips in the outer few feet at the sides and tops of the piles. With longer storage, moisture content was high throughout the piles but slightly less so in the deep interior and bottom parts.

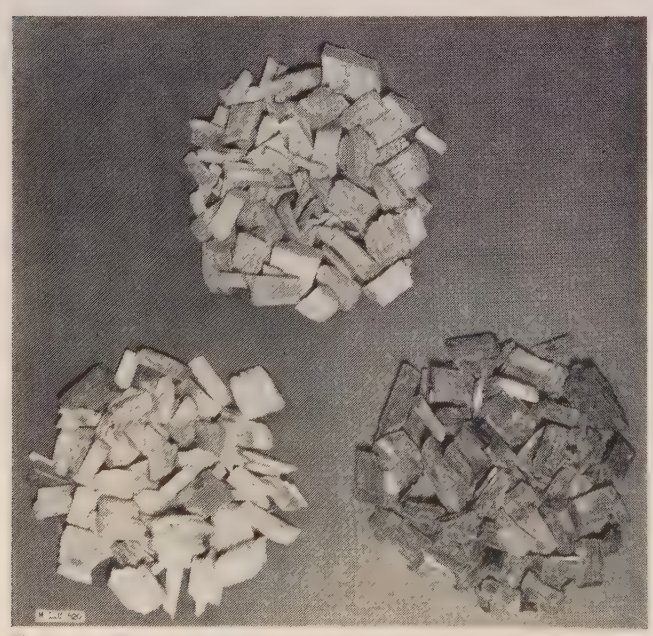

Fig. 3. Three general types of chip condition in gum storage pile

Typical decay by Basidiomycete fungus in which chips were strikingly bleached and softened (lower left); dark stain caused by soft-rot fungi, with interior bleaching of occasional chips caused possibly by typical decay fungi (lower right); nonfungus general grayish discoloration but no visible infection (upper). A fourth type, mold and light stain, is not shown.

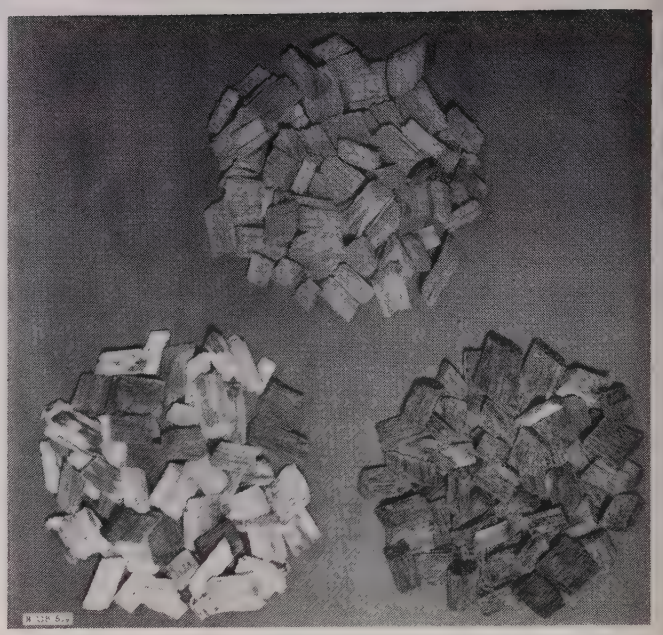

Fig. 4. Three general types of chip condition in oak storage pile

Mixture of dark stain and chips bleached by typical Basidiomycete fungus (lower left); dark stain caused by soft-rot fungi, with interior bleaching of occasional chips caused possibly by typical wood-decay fungi (lower right); nonfungus general brown discoloration, but no visible infection (upper). A fourth type, mold and light stain, is not shown.

Temperatures in all piles during the first 1 to 2 months of storage increased appreciably in the interior and, in some cases, approached 145°F., or about a 60°F. increase. The largest increase was in the pine and oak piles. After about 2 months, temperatures dropped in the pile interior but almost always remained above outside conditions. Temperatures in the outer shell of the piles tended to follow outside conditions.

Overall specific gravity of the chips decreased in all piles with longer storage. This reduction occurred largely in the outer few feet of the sides of the piles, which was the least-compacted part. Losses in specific gravity in the interior of the pile were low, even after 12 months of storage. Somewhat higher, but still rather low, losses occurred close to the top but away from the sides of the piles. Winter storage of pine chips led to somewhat lower reductions in specific gravity than summer storage, probably because temperatures in the outer sides of the piles, where fungus attack was concentrated, tended to follow outside conditions. Overall specific gravity was reduced 0.6 and 1.4% per month in the two pine piles, 2.5 to 3.0% in the gum, and about 1.5% in the oak pile. These overall losses are considered higher than are likely to occur for the much larger piles that would be used in commercial practice.

There was a close relation between the amount of fungus infection and losses in chip specific gravity in the piles. Therefore, fungus infection was concentrated largely in the outer few feet of the sides of the piles. Progress of infection inwardly from the sides and top was slow. Chips in the interior of the piles showed no, or only light, infection after storage periods of 6 to 12 months. Infection also tended to be low toward the top but away from the sides. Fungus infection in the piles will be described in greater detail later.

Pulping of the pine chips indicated that there was no

loss in percentage yield based on wood charged to the digester. Loss of pine pulp strength amounted to 4 to 5% per month, and these reductions were largely in tearing resistance. Data on pulping results for the hardwoods have not been analyzed but will appear in a paper being prepared by the cooperators.

Wetting of a gum pile as a possible method of reducing deterioration led to only slightly lower overall losses in specific gravity than occurred in the unwetted pile. However, the trial was considered inconclusive because of inability to follow the intended wetting schedule at all times. After 6 months, this pile had about a 5% higher moisture content, wet-weight basis, than any of the other piles.

Types of Infection

Pine. For both pine piles, infection of the chips is classified most conveniently into four broad groups: mold or light stain, dark stain, typical decay, and nonfungus discoloration (Fig. 2).

Mold or light stain usually was confined to the surfaces of the chips. It became evident in a few chips during the first month and was increasingly common with longer storage. Only minor losses in specific gravity of chips were associated with such infection.

Dark stain apparently represented a more advanced stage of infection by some of the same organisms that caused mold or light stain. Chips with such stain usually were discolored throughout and, with longer storage, tended to show varying amounts of softening and brashness of the surface. Dark stain appeared in a few chips after 2 months of storage and was increasingly common thereafter. Apparent losses in specific gravity of chips with dark stain were as high as 8 to 10% at the end of storage.

Typical decay, as caused by Basidiomycete fungi, showed a straw-colored bleaching and pronounced softening of the wood. It became evident only as localized spots in a small proportion of the chips in one pile, after 9 to 12 months of storage. Losses in specific gravity of chips with such infection were about 12%.

Nonfungus discoloration was typified by a general yellowing or browning of the chips, with no visible evidence of fungus infection or significant effect on the wood. It appeared to be an off-color produced by chemical or bacterial action, possibly in association with heat. Discoloration of chips was evident within the first month of storage and, except for some darkening, showed little later change. It was typical of chips in the interior of the piles, where losses in specific gravity seldom exceeded 3% even after 12 months of storage.

Gum and Oak. For gum and oak piles, infection of the chips can be classified satisfactorily into the same groups used for pine (Figs. 3 and 4).

Chips with mold and light-stain infection showed fungus discolorations on the surfaces, which only occasionally had penetrated into the interior wood. They became evident within the first month of storage and thereafter increased in prevalence in the outer few feet of the sides of the piles. Specific gravity of chips with this type of infection usually was not reduced more than 5 to 8%. Eventually, chips with such infection seemed to develop into the dark-stain types.

Dark-stained chips were almost black, often showed a beadlike growth on the surfaces, and usually were discolored throughout (Fig. 3). They were increasingly common in the shell of the piles after 2 months and, with longer storage, became softened and brash at the surfaces. After 6 months, chips with dark stain often were reduced 10 to 15% in specific gravity and sometimes close to 20%.

Typical decay in gum chips was characterized by a pronounced bleaching and eventual softening throughout the wood (Fig. 3). In gum, a general orange to yellow coloration of chips in early stages of infection was followed by a yellowish-white bleaching of the wood. Such decay was evident within the first month and became more prevalent in the shell of the pile with longer storage. After 6 months, specific gravity of chips with this type of infection usually was reduced 20 to 25% and sometimes as much as 30%. In addition to this general decay, an occasional bleaching and softening of the interior wood of gum chips with dark stain apparently was caused by typical decay fungi. In oak, bleached chips usually occurred in mixture with darkly stained ones, and partial rather than general attack of the chips was more common than in gum (Fig. 4). Furthermore, bleaching did not become evident until rather late in the 6-month storage period. In many cases, typical decay leading to bleaching seemed to involve attack of chips that already had dark stain.

Nonfungus discoloration in gum chips showed a grayish off-color, whereas the oak chips were definitely brown (Figs. 3 and 4). As in pine, these discolorations appeared to be the result of chemical or bacterial action, possibly in association with heat. They were evident within the first month or two of storage and were typical of the chips in the interior of the piles. Chips with only such discoloration usually had undergone minor changes in specific gravity after 6 months of storage, especially in the oak pile.

Comparing the three hardwood piles, general types of infection and location of infection in the pile were closely similar. Infection of all types developed somewhat more slowly in the oak than in the gum piles. Principal differences between the unwetted and wetted gum piles were that bleached chips resulting from typical decay were much less common and appeared considerably later in the wetted pile. Indications were that infections of the dark-stain type were relatively more important in the wetted than in the unwetted pile.

Organisms Causing Infection

A variety of fungi were associated with chip infection, as disclosed by surface fructifications, culturing from the wood, and microscopical examinations. Bacteria were common in most chips, but no effort was made to identify them.

In pine chips, such common molds and wood-staining fungi as *Ceratocystis, Trichoderma, Aspergillus,* and *Gliocladium* were found rather frequently. About as frequent to much-less-so were species of *Cladotrichum, Acrotheca, Leptographium, Sporotrichum?, Melanographium?, Helicosporium, Bisporomyces, Bispora, Pestalotia,* and several white, dark, or yellow cultures that remain unidentified. Of these, at least the last four genera are known to cause a recently described type of wood deterioration known as "soft-rot," which is associated with attack by various members of the Ascomycete

and Fungi Imperfecti groups. As expected, one and possibly two typical wood-decaying Basidiomycetes, as yet unidentified, were isolated from the few bleached chips that appeared in the pine pile after 12 months of storage. The brown-colored chips with no visible evidence of infection were not necessarily free of infection, since occasional cultures of *Trichoderma*, *Cladotrichum*, and several unidentified growths, along with bacteria, were isolated from them.

In gum chips with mold and varying degrees of stain

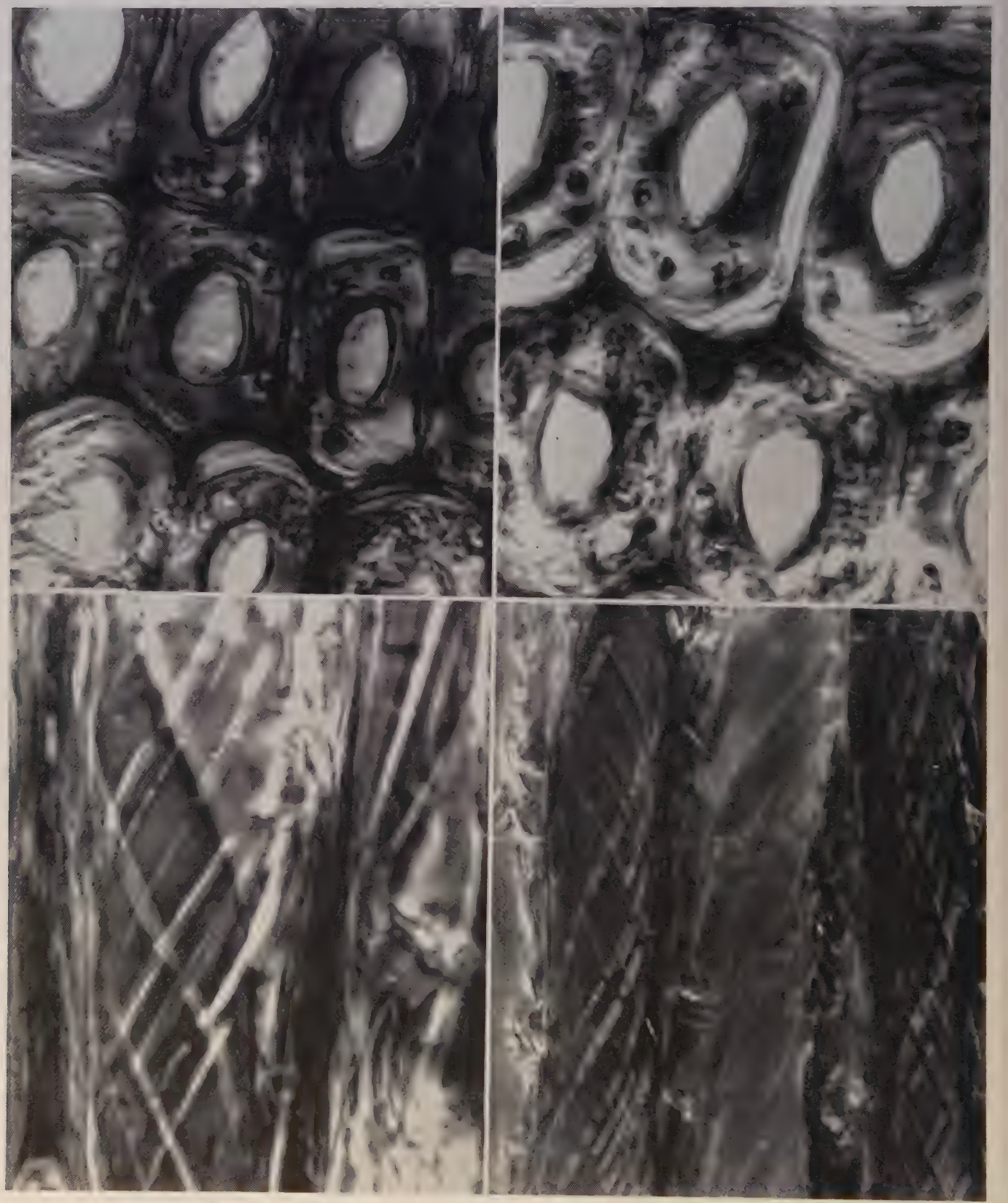

Fig. 5. Microscopical sections of pine chips

Cavities made by soft-rot fungi in the secondary walls of tracheids (upper left and right); spirally oriented hyphae and cavities of soft-rot fungi in walls of tracheids (lower left); heavy spiralling of soft-rot fungi in walls of tracheids, and chains of cavities with pointed ends (lower right).

infection, the organisms found were *Aspergillus*, *Fusarium*, *Ceratocystis*, *Trichoderma*, *Phialophora*, *Cladotrichum*, *Bactrodesmium*, *Chaetomium*, *Graphiopsis*, and *Paradiplodia*, along with bacteria. As in pine, several of these are capable of causing soft-rot in wood, including *Phialophora* which was very common in chips. Bleached chips yielded at least two wood-decaying Basidiomycetes, which are unidentified. Miscellaneous other fungi also occurred in bleached wood, but the primary organism obviously was one or more of the white-

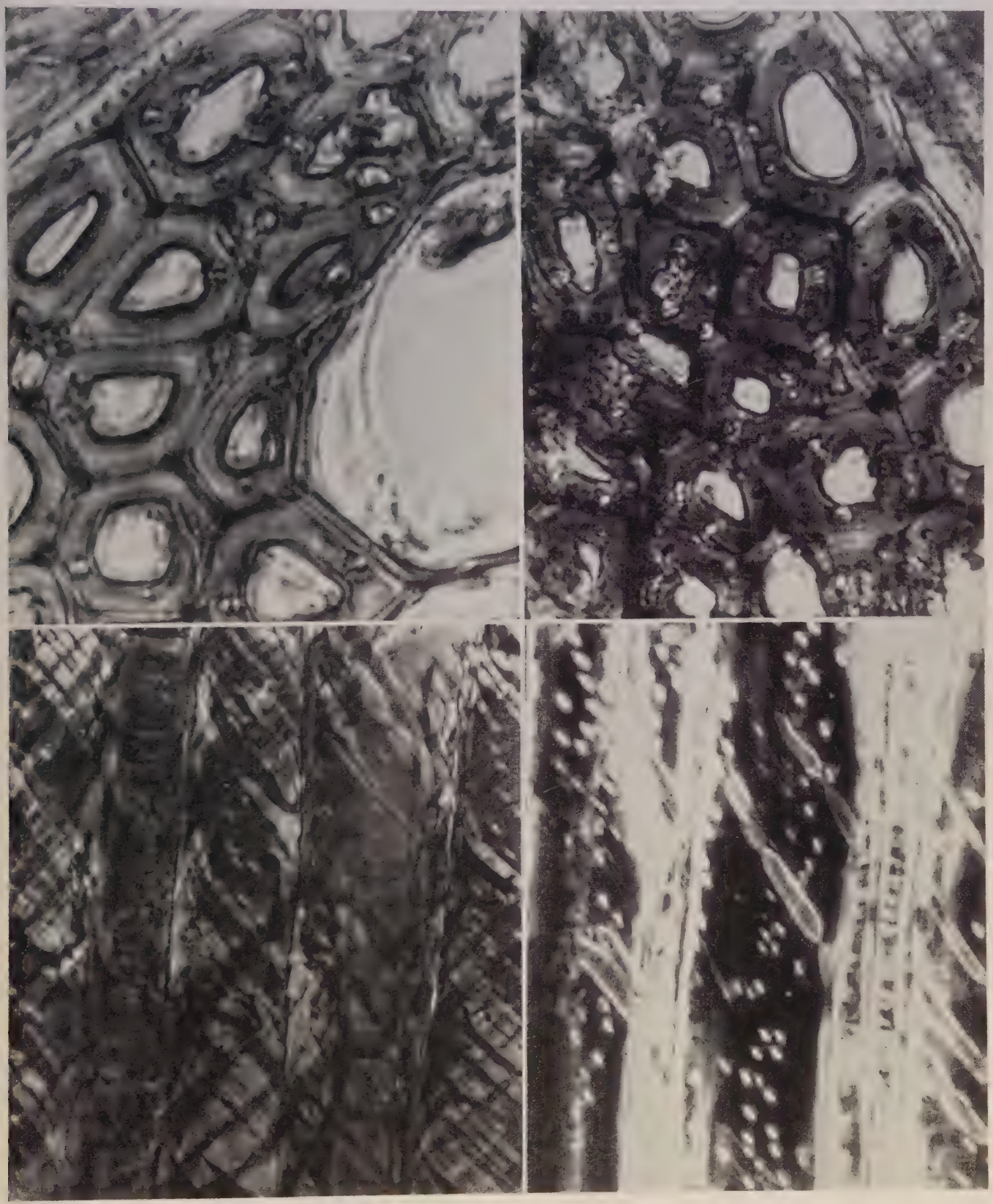

Fig. 6. Microscopical sections of gum chips

Moderate (upper left) and heavy (upper right) cavity formation by soft-rot fungi in the secondary walls of fibers; spirally oriented hyphae and cavities in fibers heavily attacked by soft-rot fungi (lower left); chains of cavities with pointed ends which are typical of soft-rot attack (lower right).

rot decay fungi. Chips with a nonfungus general discoloration but no visible fungus infection yielded occasional cultures of *Aspergillus, Trichoderma,* and *Phialophora,* along with bacteria. There were no clear-cut differences in types of fungi between the unwetted and wetted gum piles.

Oak chips were infected with organisms that were closely related to those in gum. Along with bacteria, some of the earliest infection in molded and stained chips was associated with such fungi as *Ceratocystis, Gliocladium, Paradiplodia, Penicillium, Trichoderma, Aspergillus,* and *Fusarium.* Common other fungi that soon appeared were species of *Phialophora, Spicaria, Pestalotia, Spondylocladium, Bactrodesmium, Graphiopsis,* and *Arthobotrys,* several of which cause soft-rot. As in gum, two typical wood-decaying Basidiomycetes of unknown identity were isolated from chips with bleached areas. Chips with only a general brown discoloration that was of nonfungus origin usually yielded bacteria only.

Effects on Wood by Important Fungi

Microscopical examinations revealed that the most common chip damage was caused by fungi that had attacked the secondary walls of tracheids or fibers. Such attack was evident in chips with mold and light-stain infection, and was most pronounced in dark-stained wood. It also occurred in some of the chips that had been bleached and decayed by Basidiomycetes, but was not observed in chips with only nonfungus discoloration. It was apparent, therefore, that practically all deterioration of pine and an important part of that of gum and oak chips had been caused by soft-rot fungi (*6, 21, 22*).

In wood with soft-rot, the fungi grow spirally in the highly cellulosic secondary walls of tracheids and fibers, producing chainlike cavities with pointed ends (Figs. 5 and 6). Wood at the surface, where attack is most severe, may show almost complete destruction of the secondary walls, with little evidence of fungus hyphae. In interior areas of advancing rot, the cells contain many hyphae, occasional fruiting structures, and often bacteria. The attack in hardwoods sometimes is not as distinct as in pine, and may appear as closely packed hyphae and cavities that extend longitudinally in the fibers. Wood with soft-rot has characteristics that resemble decay caused by both brown- and white-rotting Basidiomycetes (*22*). Cellulose constituents of tracheid and fiber walls are attacked primarily, however, so that highly lignified areas of the primary wall and middle lamella are not greatly affected.

Other qualities described for soft-rot are that it darkens, softens, and causes brashness of the surfaces and as it developes inwardly in wood (*6, 21*). The rate of attack is slower than that of Basidiomycetes, except under conditions of either high or low moisture levels in wood that are unfavorable for the typical wood-decay fungi. It also usually is slower in softwoods such as pine than in hardwoods such as gum and oak.

The type (Fig. 1) and significance of damage caused by wood-decaying Basidiomycetes were described earlier. Such attack was observed in chips that were bleached and often greatly reduced in specific gravity of the wood. In pine and oak particularly, soft-rot also was present in most chips of this type. However, decay by Basiodiomycetes appeared to be the principal cause of wood destruction where both types of damage occurred. Based on visual and microscopical examinations of the chips, damage by typical wood-decay fungi was minor in the pine pile but equally or more important than that by soft-rot in the unwetted gum pile. In the oak and wetted gum piles, losses associated with soft-rot probably were predominant.

Factors That Influenced Infection

Undoubtedly, the principal factors that influenced infection of the chips were temperature, moisture, and oxygen conditions in the piles. In this connection, a number of the fungi that cause soft-rot in wood are capable of growing at higher levels of temperature, moisture, and pH than are tolerated by wood-decaying Basidiomycetes (*6*). This is not surprising, considering the large variety of Fungi Imperfecti or Ascomycetes that now are known or suspected to infect wood.

Temperatures that were most favorable for chip infection occurred in the shell at the sides of the piles where they approached those of the outside atmosphere. Interior pile temperatures during the first few months of storage were not only too high for growth but probably had some pasteurizing effect. These temperatures commonly exceeded 130°F. and were as high as 145°F. Most fungi are killed when exposed to moist heat for 24 hr. or longer at 140°F., or for several hours at 150°F. The heat factor, therefore, could have been important in the absence of infection in pile interiors. The extent to which this temperature increase was related to organisms that were present during early storage is not clear. Heating in large piles of stored grain was first though to be due to autolytic enzymatic changes, but more recent evidence suggests that fungi or bacteria play an important role.

The moisture requirements of wood-decaying Basidiomycetes are fairly well known, especially in solid wood products. Minimum and optimum moisture levels for growth in most woods are about 18 and 28 to 45%, wet weight, respectively. Maximum, and also optimum, moisture levels vary with density of the wood but usually range between 50 and 65%. Specific moisture requirements for soft-rot infection of wood have not been determined, but some of these organisms are reported to attack wood that is either too wet or too dry for growth of the Basidiomycetes. Supporting this evidence is the fact that soft-rot was more and typical wood decay less important in the wetted than in the unwetted gum chip piles. Moisture content of the chips increased appreciably in all piles and, after 4 or 5 months, reached levels that probably favored fungi of the soft-rot type. The relation of fungus infection to this increase of chip moisture was complicated by rain seepage and condensation within the pile, due to internal heating. However, metabolic water is an end-product of wood infection; therefore, organisms must have had some part in the changes of chip moisture during storage.

Wood-attacking fungi, but not all bacteria, are aerobic, so that an adequate supply of oxygen is essential for growth. Examples of insufficient oxygen to support decay are found in wood stored under water or buried deeply in soil. The amount of oxygen needed by Basidiomycetes apparently is small; normal growth may

continue until the supply is $^1/_{10}$ to $^1/_{15}$ that present in the atmosphere, and is not stopped completely until amounts approach $^1/_{50}$ or less (*23*). Most fungi also can tolerate a wide range of concentration of carbon dioxide. Since soft-rot fungi attack wood that is too wet for Basidiomycetes, it is probable that some of them at least, need less oxygen for growth. It is interesting to note that important infection in the chips was limited largely to the least compacted sides of the piles where oxygen was most plentiful. It appears that the limited amounts of oxygen in the compacted parts of the piles, especially in the interior, might soon have retarded fungus growth. However, the absence of infection in these areas cannot be attributed entirely to oxygen deficiency, since highly unfavorable temperatures also developed in these parts of the piles.

It appears that general conditions in the piles were more favorable for attack of the chips by soft-rot than by wood-decaying Basidiomycetes. Somewhat similar conditions apparently are encountered in large piles of stored grain, and it is interesting that some of the organisms reported to cause deterioration of grain are closely related to the fungi associated with soft-rot in chip piles.

GENERAL DISCUSSION

The five storage piles of pine, gum, and oak chips were similar in indicating that fungus damage was concentrated largely in the shell at the sides of the piles, moisture content of the chips increased appreciably, temperatures in the interior of the piles rose markedly during the first 2 or 3 months of storage, and attack by soft-rot organisms was an important cause of deterioration of both pine and hardwood chips. Of the three woods, gum showed the most and pine the least deterioration. Infection extended gradually into pile interiors as storage periods lengthened, and tended to be deepest in the gum piles. Bacteria were generally present and may have been a factor in some of the temperature, moisture, and discoloration aspects of storage.

The results of these studies are believed to indicate that lower losses due to fungus attack can be expected from storing southern pine in chip than in rough pulpwood form. Since chip infection during 6 to 12 months of storage was confined largely to the shell of the piles, particularly at the sides, overall losses in chip storage would be expected to decrease with increase in size of pile. Therefore, any differences between the two methods in the study piles should be accentuated by the use of much larger piles in practice. The picture is not so clear for hardwoods, since gum, and oak to some extent, showed higher overall losses in chip density than have been recorded for stored rough pulpwood. Considering the factor of larger piles in practice, it appears that overall chip damage would be as much or slightly more in gum and about the same or slightly less in oak piles than usually occurs in stored rough pulpwood.

The extent to which results from the present studies might apply to other woods stored in regions of different climate can only be speculated. Seasonal influences apparently affect chip as well as roundwood deterioration, because temperatures in the pile shell, where infection was greatest, tended to reflect outside conditions. There is some evidence for softwoods, at least, that losses in storing chips elsewhere are not excessive. The reported experience of western mills, for example, has been consistently encouraging. In Sweden (*1*), chips in the interior of piles have been observed to be remarkably well preserved after extended storage. The nonfungus browning of interior chips that occurred in the present studies was observed also in Sweden.

Opportunities are not lacking for reducing losses in chip as well as in pulpwood storage. Wetting of the gum chips with water was attempted in these studies with only small success, but the trial is considered inconclusive because of lapses in the intended watering schedule. The application of fungicidal chemicals to chips offers possibilities, provided costs are not too high. Since losses due to fungus attack are greatest in the shell of piles, damage might be considerably reduced by applying water or chemicals only to the chips in these areas.

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Dialdehyde Starch Retention by Use of Cationic Starch for High Wet-Strength Paper

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Studies have been made on the use of cationic starch as an alternative to alum as a retention aid in the wet-end addition of dialdehyde starch (DAS). Practical optimum conditions of application were established by studies of concentration and amount of additives employed, sequence of addition, and influence of pH, time, and temperature. The amount of additive retained and the physical properties of paper made from a variety of pulps were determined. The degrees of wet strength imparted were found to vary somewhat with the kinds of pulps used. For DAS retentions of 0.5 to 0.8%, dry pulp basis, the average wet tensile obtained for the representative pulps was 40% of the untreated, dry control paper with a maximum value of 60%. Either DAS or cationic starch used alone contributes to dry strength increases, and substantial increases result from the use of combinations.

Dialdehyde starch (DAS) imparts a high degree of wet strength to paper when utilized as either a tub-size (*1*) or as a wet-end additive in conjunction with alum (*2*). In addition to the outstanding wet strengths achieved, significant increases in other paper properties, particularly dry strength, are realized. The principal problem associated with the wet-end addition of DAS in bisulfite dispersion is its complete lack of affinity for cellulose fibers. Although alum has been successfully used to obtain DAS fiber substantivity, the high concentrations required present operating difficulties.

Cationic moieties have been used as a means of inducing an affinity of cellulose fibers for anionic papermaking additives. It therefore appeared desirable to investigate the use of cationic materials as retention aids for DAS. Examination of a number of commercial cationic products showed that cationic starches are excellent for this purpose; hence, they were investigated extensively.

Cationic starches containing basic tertiary- and quaternary amine groups are efficiently retained in cellulose fibers, improve paper quality, and have been employed as retention aids for fillers. In the present work, DAS-cationic starch combinations were investigated to establish practical operating conditions for their use as wet-end additives in the preparation of wet-strength paper. The papers prepared under the optimal conditions developed had outstanding wet strength and improved dry strength. In addition to handsheet data, experimental trials were made on a laboratory fourdrinier machine.

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MATERIALS AND METHODS

DAS was prepared at this laboratory by oxidation of pearl cornstarch to 96% of theory with periodic acid (*3*). Because proper dispersion of DAS is critical to its successful application to paper, previously defined dispersion conditions (*2*) giving optimum results were followed. Essentials of the dispersion conditions are a controlled cooking at 92°C. of 3% aqueous slurries of DAS containing 15% sodium bisulfite (based on DAS weight) for the periods of time required to pass through a viscosity maximum and return to near-waterlike consistency. Although pearl cornstarch was used for the preparation of DAS, starch from other sources including milo, wheat, waxy maize, tapioca, amylomaize, and potato were also tried and were about equally effective when applied as DAS to paper under the preferred conditions.

A number of commercial and experimental cationic starches were evaluated as retention aids for DAS. The solubility and viscosity properties of the different cationic starches examined varied greatly. In initial trials some types were quite ineffective for DAS retention. Several products, however, were about equally effective on the basis of limited trials. All experimental results reported in this paper were obtained using one commercially available cationic starch. Variation in handling procedures might be required for optimal results if other types of cationic starches are used. Dispersion conditions are not critical although complete granule gelatinization must be obtained, which requires only a brief cooking of 3% aqueous slurries at about 92°C.

A western bleached softwood kraft pulp (S.-R. freeness 700 ml.) was used for experimental evaluations. Representative commercial pulps were investigated to estimate the overall range of effectiveness of the DAS-cationic starch treatment.

Tapwater had a hardness of about 340 p.p.m. (calculated as calcium carbonate) and an alkalinity of 140 p.p.m.

Handsheets were prepared and conditioned according to TAPPI Standard Methods. The general procedure for the treatment of pulp and handsheet preparation was as follows: to a continously stirred pulp suspension (0.375% consistency) the cationic starch dispersions (0.6% concentration) were added with no pH adjustments. After a minimum of 2 min. contact time of pulp and cationic starch, DAS dispersions (0.6% concentration) were added, and within an additional 2 min. the pH was adjusted to 4.5 with hydrochloric acid. Handsheets were then formed in a British sheet machine with diluent water preadjusted to pH 4.5. The addi-

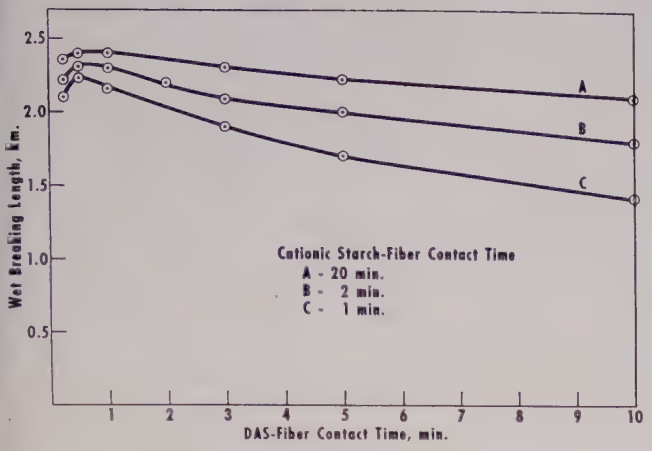

Fig. 1. Handsheet data illustrating the relationships of pulp–additives contact times and wet strength

tive–pulp contact times were chosen because they gave results near optimum and were convenient for experimental operations. Physical tests were made after 24 hr. equilibration at 50% R.H. and 23°C.

Paper machine trials were on a 10-in. laboratory fourdrinier with a pulp consistency of 0.25%. In preliminary work the minimum contact time between pulp and cationic starch was 20 min. The furnish was then acidified with hydrochloric acid to pH 4.5, the DAS added, and the machine started. However, metering in of DAS just before the wire to pulp–cationic starch slurries at pH 4.5 results in paper of more uniform quality.

Retention of DAS was determined by adaptation of an analytical method developed at the Northern Laboratory (*4*). Cationic starch retention was determined by measurement of the starch-iodine complex as described by Browning, *et al.* (*5*).

FACTORS INFLUENCING DAS RETENTION AND WET-STRENGTH DEVELOPMENT

Pulp–Additive Contact Time

Adsorption of cationic starch by pulp, under the conditions of handsheet formation described, is rapid and nearly quantitative after about 20 min. Maximum retention of DAS is obtained rapidly following its addition to the cationic starch–pulp slurries. Further contact time, however, results in a gradual decline in DAS

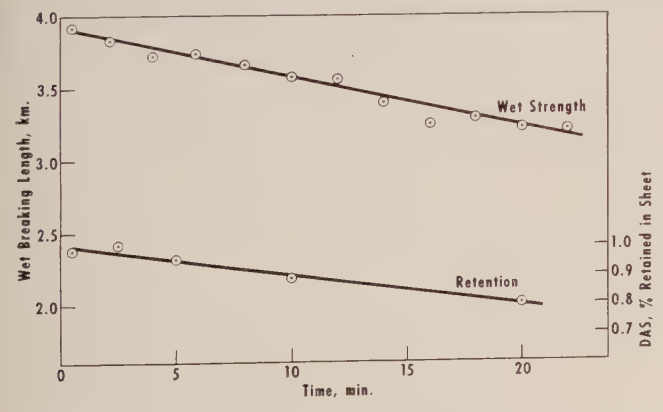

Fig. 2. Progressive changes in DAS retention and wet strength with increasing time of pulp–additive contact time in a paper machine trial

Both DAS and cationic starch applied at 2.5%, dry pulp basis.

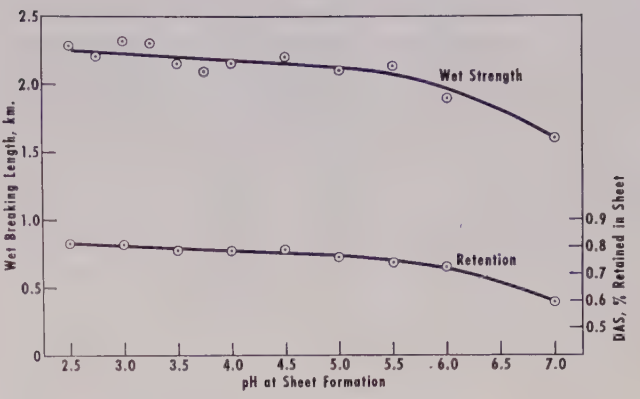

Fig. 3. The effect of pH on DAS retention and wet strength in handsheets

Both DAS and cationic starch applied at 2.5%, dry pulp basis.

retention with a corresponding loss in wet strength (Fig. 1) which apparently depends upon the prior cationic starch–pulp contact time.

Further proof that DAS retention declines with increased contact time was obtained in machine trials (Fig. 2). DAS was added to the furnish storage chest 20 min. after the cationic starch, the pH was adjusted with hydrochloric acid to 4.5, and the machine started. It is seen that the progressive loss in retention with increasing running times is paralleled by a corresponding loss of wet strength. However, metering in of the DAS just before the wire and thus allowing a contact time of only a few seconds duration resulted in a continuous production of paper having no variation in retention and wet strength. White water in the systems was not re-used.

pH of Furnish

Retention of DAS in handsheets formed within the pH range 2.5 to 5.5 is nearly constant, as is wet-strength development (Fig. 3). Cationic starch retention was unaffected by the pH variations in this range. Alteration of the sequence of additions and pH adjustment can result in changes in the response to pH. For example, acidification preceding DAS addition rather than after, results in good retention only within the pH range 4.3 to 6.0 and displays a maximum wet-strength development at 4.5

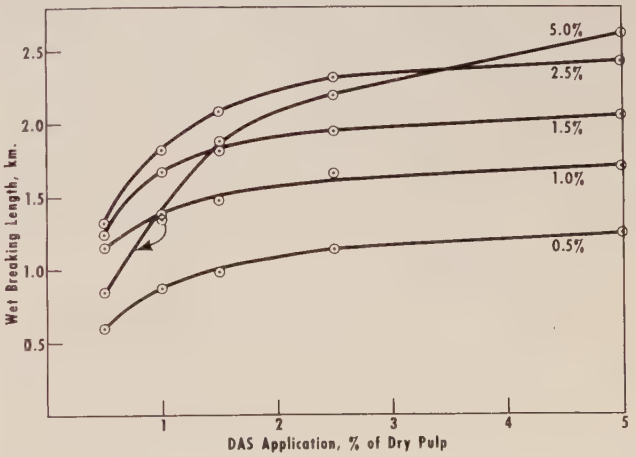

Fig. 4. Wet strengths obtained in handsheets for various combinations of DAS and cationic starch

Per cent cationic starch indicated on curve.

Table I. Application of Dialdehyde Starch to Various Pulps

Pulp[a]	Tensile strength increase, % Dry	Tensile strength increase, % Wet	Wet tensile × 100 / Control dry tensile, %
Rag	76	690	42
Alpha	240	>500	60
Bleached kraft	36	920	28
Unbleached kraft	54	1230	38
Semibleached groundwood	101	>1200	59
Unbleached semichemical	107	>1200	36
Bleached sulfite	63	1150	40
Unbleached sulfite	42	1080	31

[a] Using 2.5% cationic starch, 2.5% DAS, and pH 4.5 in tapwater. All pulps had a S.-R. freeness of about 700 ml.

Levels of Additive Application

Handsheets were prepared using varying quantities of cationic starch and DAS (Fig. 4). For a given level of DAS application to the prior treatment of pulp with increasing quantities of cationic starch from 0.5 to 2.5% was progressively effective in the improvement of retention and wet strength. However, raising the level of cationic starch application to 5.0% did not increase DAS retention or wet strength at levels of DAS application below 3.5%. When the ratio cationic starch/DAS is high, it is likely that some DAS will react with excess cationic starch which is either very loosely held at the fiber surface or colloidally dispersed.

The retention of DAS in handsheets, based on the amounts added, was less efficient at higher levels of application. For example, with a constant 2.5% cationic starch application, DAS retention was 25 and 60% for the 2.5 and 0.5% levels of addition, respectively.

Water Source

Local tapwater of extreme hardness was used in all but several special trials. The overall performance of the DAS-cationic starch wet-strength system is not significantly affected by water hardness, although results obtained in distilled water could be improved slightly by additions of sodium bicarbonate up to 75 p.p.m.

Water temperatures did not affect the results within the range 8 to 35°C. Below this limit, losses in wet strength were noted.

Pulp Type

The response to DAS-cationic starch treatment shown by pulps of different origin and physical or chemical treatment is given in Table I. The applicability of a DAS-cationic starch combination to these pulps was obtained under one selected set of conditions.

Greatest strength increases were obtained with the poorer quality pulps, such as groundwood or semichemical. Further work is planned to define more exactly these beneficial effects and their relation to conditions of application.

CONDITIONING AND PAPER STABILITY

The development of maximum wet strength does not depend upon the drying temperature because similar results are obtained either at room temperature or in drying off-the-machine. Handsheets conditioned according to TAPPI Standard Methods develop full wet strength in less than 24 hr. In machine trials full wet strength is developed almost as soon as the paper is dried.

Table II. Physical Properties of Machine Paper Containing Dialdehyde Starch

Test	Bleached softwood kraft, S.-R. 700 ml.	Treatment: 2.5% Cationic starch	Treatment: 2.5% Cationic starch and 2.5% DAS	Treatment: 11% Alum and 2.5% DAS
Burst factor, g./cm.²/g.s.m.	49	71	81	69
Tear factor, g./g.s.m.	255	175	168	168
Breaking length, km.				
Dry, M.D.	8.5	11.3	12.5	11.4
Wet, M.D., 30 min.	0.27	0.37	3.33	3.39
Schopper fold	1800	2100	2600	1900
Water absorption (Cobb), g.s.m.-min.	117	88	68	64
Brightness (Hunter), %	72	74	72	70

The effect of extended storage of DAS–cationic starch treated papers (2.5% levels of addition) at various relative humidities (temperature constant at 23°C.), on wet-strength properties, an important practical consideration, was investigated. Below 80% R.H. wet strength remained unchanged at the end of a 6-month storage period. After storage for 6 months at 100% R.H.. wet strength decreased 50% of the original value.

Intermittent exposure of treated sheets to artificial light over the course of a year resulted in a 9% loss in brightness (Hunter). No changes in brightness were observed when these papers were kept in the dark.

DAS-treated paper can easily be repulped in either hot water (50°C.) or in water at 25°C. adjusted to pH 11. With only a mild stirring action, paper treated with 2.5% cationic starch and 2.5% DAS was completely repulped in less than 10 min. using either set of conditions. Nearly complete removal of DAS was readily accomplished under mild conditions with no apparent damage to the fibers—an important consideration in broke recovery.

GENERAL PHYSICAL PROPERTIES

The physical properties and the degrees of change obtained by incorporation into paper of cationic starch alone and of DAS–cationic starch and DAS-alum combinations are compared in Table II. Cationic starch alone, which is nearly 100% retained, gives substantial dry strength increases under conditions leading to those at which DAS is usually applied. General upgrading of paper properties, with the exception of tear resistance, is excellent.

DISCUSSION

The use of cationic starch results in DAS retention in practical quantities with the consequent development of a degree of wet strength having commercial value. Cationic starch, aside from its basic function as a retention aid, contributes significantly *per se* to strength properties of paper. Both DAS and cationic starch dispersions are easy to prepare, and the conditions of application can conveniently be adapted to conventional papermaking equipment and procedures.

Aqueous colloidal bisufite dispersions of DAS and cationic starch precipitate if mixed at the concentrations used in their application. Probably retention of anionic DAS results from its attraction to the cellulose fiber surfaces by cationic starch. Thus far, retention of DAS, regardless of conditions or amounts applied, has not exceeded 1.2% (dry pulp basis). The

wet strength developed by DAS is dependent both on the conditions under which it is incorporated into paper and on the actual amounts retained.

Increasing the pulp contact time with cationic starch at a 2.5% level of application results in a progressive and an eventual exhaustive adsorption of the latter. Indications are that addition of DAS at any point prior to substantial adsorption of the cationic starch by the fibers, or before an equilibrium has been established, would result in less efficient use of the DAS and cationic starch added. Cationic starch attached loosely to the fibers after only a brief contact time might react with DAS but merely result in a superficial retention with little wet-strength production.

The development of the present procedures has been of an empirical nature. A knowledge of the details of the mechanism of retention and of wet-strength development in this system is highly desirable.

SUMMARY AND CONCLUSIONS

The use of cationic starch at moderate yet effective levels of application to retain DAS in wet-end additions has been demonstrated. Optimum use conditions described are believed to be consistent with industrial operating procedures. The advantages of cationic starch over alum as a DAS retention aid are numerous and decisive for its preferred use.

In addition to the general upgrading and improvement of wet-strength properties, the following operating advantages are obtained:

1. Effective performance in the pH range 2.5 to 5.5.
2. Lack of sensitivity to water source (degree of hardness).
3. No heat treatment required for development of full properties.
4. Ease of broke recovery.
5. Ease of preparing a stable DAS dispersion, requiring no aging.
6. Good stability of treated papers on aging.
7. Highly effective for a variety of pulps to produce both wet- and dry-strength increases.
8. Both cationic starch and DAS are commercially available.

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Decomposition of Lignin

I. Action of Compounds of the Type $RNH_{1-3}X$

Donald H. GRANGAARD

Earlier it had been observed in demethylating lignin with certain compounds of the type $RNH_{1-3}X$, that besides the demethylation a more deep-seated reaction occurred with the result that catechol was formed in considerable yield. Subsequent experiments carried out on model compounds indicate that compounds which possess a structure of the dihydroxydiphenylmethane type, or are capable of reacting with themselves, or with the amine, to form compounds of this type, are decomposed in a manner such that simple phenols result. Application of these results to lignin suggest that the catechol observed as a decomposition product probably arises from a guaiacylglycerol type of structure within the lignin. The structure of the dihydroxydiphenylmethane type necessary as a prerequisite to the decomposition arises as a result of the condensation of the amine with the free secondary alcohol group which exists in the guaiacylglycerol structure. The results obtained also suggest that when lignin is reacted with an amine, or a phenol, using an acid catalyst, the linkage formed is probably a carbon-to-carbon rather than an amino or ethereal linkage.

Some years ago (*1*) during attempts to demethylate lignin, using as the demethylating agents (*2–4*) compounds of the type $RNH_{1-3}X$, the observation was made that along with the demethylation a more deep-seated reaction occurred with the result that catechol (*o*-dihydroxybenzene) was formed in considerable yield. About the same time it was also observed that certain cured phenol-formaldehyde resins likewise were decomposed by reagents of this type. Further, it was found that 4,4′- dihydroxydiphenyldimethylmethane (bisphenol-A) was decomposed. On the other hand, compounds such as *p-tert*-butylphenol and *p*-phenylphenol were not decomposed. The ability of the reagent to decompose a compound such as bisphenol-A but not those such as *p-tert*-butylphenol and *p*-phenylphenol suggested that the reagent might be specific for a certain type of grouping, namely, the dihydroxydiphenylmethane group. The possibility of a structure of the dihydroxydiphenylmethane type in lignin has considerable merit. Certain of the lignans, a group of naturally occurring compounds believed by many to be closely related to lignin, contain structures of this type (see Fig. 1). The ability to show conclusively that the catechol arises from a structure of this type in lignin could help materially in elucidating the ultimate structure of lignin.

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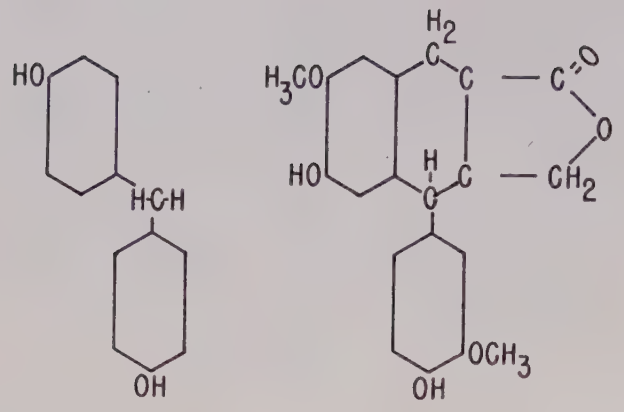


Fig. 1. The dihydroxydiphenylmethane structure

EXPERIMENTAL

Materials

The majority of the benzene and phenol derivatives were obtained either from Distillation Products Industries (Rochester, N. Y.) or from K&K Laboratories, Inc. (Jamaica 33, N. Y.). The veratraldehyde was obtained from the Mathieson Co. (East Rutherford, N. J.), and the bisphenol-A, *p*-phenylphenol and *p-tert*-butylphenol from the Dow Chemical Co. (Midland, Michigan). The conidendrin and part of the dehydrodiisoeugenol was obtained through the courtesy of Dr. Pearl of the Institute of Paper Chemistry, Appleton, Wis. The remainder of the dehydrodiisoeugenol was prepared according to the procedure of Leopold (*5*). The vanillalaniline was prepared according to the procedure of Carré and Baranger (*6*).

Aniline Hydrochloride. This was prepared by adding an excess of concentrated hydrochloric acid to aniline. After the reaction mixture had cooled, the aniline hydrochloride was separated by filtration, washed with 95% ethyl alcohol, and air-dried (m.p. 196-198°C.). It was used without further purification.

Triethylamine Hydrochloride. This was prepared by passing dry hydrogen chloride gas into a mixture of 200 ml. of triethylamine and 150 ml. of 95% ethyl alcohol until the mixture solidified. The mixture was cooled, the triethylamine hydrochloride separated by filtration, washed with 95% ethyl alcohol and air-dried (m.p. 251–253°C.). It was used without further purification.

Diisoeugenol. Fifty grams of isoeugenol and 100 g. of aniline hydrochloride were heated on a steam bath for 3 hr. The reaction mixture, after dissolving in 150 ml. water, was extracted with ether (800 ml.). The ether extract, after washing twice with 100 ml. of water, was distilled to remove the ether. The semicrystalline residue which formed was recrystallized from a mixture of benzene and petroleum ether (yield 26.3 g.; m.p. 173-175°C.). The melting point after recrystallization from benzene–petroleum ether was 178 to 180°C. Haworth and Mavin (*7*) report a m.p. of 180 to 181°C. for this material.

3-Methoxy-4-hydroxy-4′,4″-diaminotriphenylmethane. This was prepared essentially according to the procedure of Weil, *et al.* (*8*) for preparing 4-hydroxy-4′,4″-diaminotriphenylmethane. The procedure follows:

One hundred grams of vanillin, 296 g. aniline, and 11.2 g. aniline-HCl were heated together, under reflux and with stirring, at 135 to 140°C. for 7 hr. The reaction mixture was cooled, neutralized with sodium bicarbonate, and steam-distilled to remove excess aniline. The resulting semisolid residue, after decantation of the aqueous layer, was taken up in about 500 ml. of 95% ethyl alcohol. Concentrated hydrochloric acid, 150 ml., was next added and the mixture set aside in a cool place. The resulting crystals were removed by filtration, washed and air-dried (wt. 93.0 g.). After recrystallization from 95% ethyl alcohol containing a little concentrated hydrochloric acid: m.p. 225–227°C. (decomp.).

Anal.: $C_{20}H_{22}ON_2Cl_2 \cdot 2C_2H_5OH$—Calcd.: $NH_2 = 6.84\%$, Cl = 15.2%. Found: $NH_2 = 6.86\%$, Cl = 15.7%.

Procedures

General Reaction Procedure. In a suitable flask fitted with a stirrer, a thermometer, a reflux condenser, and a gas inlet tube was placed one part by weight (p.b.w.) of the compound and 5 p.b.w. of the amine hydrohalide. The mixture was heated by means of a glass mantle or oil bath. As soon as a melt was obtained, a slow stream of dry hydrogen chloride gas was allowed to pass into the reaction mixture throughout the remainder of the heating period. A temperature of 220 to 240°C. was maintained for about 3 hr. The reaction mixture, after cooling to 170 to 180°C. was cautiously diluted with approximately 4 p.b.w. of water. The mixture was allowed to cool to room temperature. Approximately 0.5 p.b.w. of concentrated hydrochloric acid was added and the mixture extracted with ether. The ether extract, after drying over anhydrous sodium sulfate, was distilled to remove the ether. The phenol, or catechol, in the residue was then isolated by one of the following procedures:

(a) The residue was dissolved in an equal weight of hot toluene, and the resulting solution heated to a temperature of 104 to 106°C. for approximately 1 min. The solution was then placed in a cool place to crystallize. If no crystallization:

(b) The toluene solution was extracted with water, and the water extract, after saturation with sodium sulfate, extracted with ether. This ether extract, after drying over anhydrous sodium sulfate, and after distillation to remove the ether was treated as in (c).

(c) The residue was transferred to a sublimation flask, and after evaporation to dryness, the catechol recovered by sublimation *in vacuo*. The sublimate was then recrystallized from hot toluene.

(d) In the instances where phenol was the potential reaction product, the residue was transferred to a distillation flask and the free phenol recovered by distillation at atmospheric pressure.

Reaction of Aniline Hydrochloride and Bisphenol-A. Fifty grams of bisphenol-A and 250 g. aniline hydrochloride were treated as in the general reaction procedure. Concentration of the ether extract gave 35.6 g. crude phenol. The remaining reaction mixture was neutralized with sodium bicarbonate and steam-distilled to remove the excess aniline. After cooling, the mixture was extracted with ether (three times), and the ether extract concentrated. This gave 18.3 g. of a semicrystalline residue which was taken up in hot ben-

Table I. Types of Groups Eliminated

Compound	*Basic formula*	*Group eliminated*	*Product*
Bisphenol-A	$HO—Ph.—C(CH_3)_2—Ph.—OH$	$—C(CH_3)_2—$	Phenol
4-Hydroxybenzophenone	HO—Ph.—COPh.	—COPh.	Phenol
Vanillin	$HO—Ph.(OCH_3)—CHO$	—CHO	Catechol
Vanillic acid	$HO—Ph.(OCH_3)—COOH$	—COOH	Catechol
o-Hydroxybenzyl alcohol	$HO—Ph.—CH_2OH$	$—CH_2OH$	Phenol
Isoeugenol	$HO—Ph.(OCH_3)—CH=CHCH_3$	$—CH=CHCH_3$	Catechol
Eugenol	$HOPh.(OCH_3)—CH_2—CH=CH_2$	$—CH_2—CH=CH_2$	Catechol
Vanillalaniline	$HOPh.(OCH_3)—CH=NPh.$	—CH=NPh.	Catechol

zene. After cooling, the benzene solution was treated with dry hydrogen chloride gas. The resulting precipitate was removed by filtration and air-dried (wt. 22.3 g.). On recrystallization from hot isopropyl alcohol a material melting at 257 to 260°C. (with decomposition) was obtained. A weight of 7.05 g. of this material was dissolved in dilute hydrochloric acid, cooled to 3 to 5°C., and treated with 4 g. sodium nitrite in 10 ml. water. After a few minutes, the solution was heated on a steam bath and held at 40 to 60°C. for about 30 min. The solution was cooled and the gummy precipitate removed by extraction with ether. Concentration of the ether extract gave a small amount of a gummy residue. Extraction of this residue with hot water gave an aqueous extract which, upon cooling, crystallized. After air-drying, the crystals melted at 156 to 157°C. The melting point is not depressed by admixture with an authentic sample of 4,4′-dihydroxydiphenyldimethylmethane.

Reaction of Aniline Hydrochloride and Anisyl Alcohol. Fifty grams of anisyl alcohol and 250 g. aniline hydrochloride were treated as in the general decomposition procedure. Concentration of the ether extract gave 22.1 g. of crude phenol. The remaining reaction mixture was neutralized with sodium bicarbonate and steam distilled to remove the excess aniline. After cooling, the solution was extracted with ether (three times). Concentration of the ether extract gave 69.2 g. of a sirupy residue. This residue was taken up in hot benzene. Upon cooling 6.05 g. of a crystalline material melting at 145 to 147°C. was obtained. The melting point after recyrstallization from benzene was 149 to 150°C.

This material was suspended in benzene and treated with dry hydrogen chloride gas. The product was removed by filtration, washed with benzene and air-dried. It was recrystallized from concentrated hydrochloric acid (m.p. 233-234°C.). This material was identified as 4-methoxy-4′-aminodiphenylmethane hydrochloride.

The remaining benzene solution was treated with dry hydrogen chloride gas. This caused a heavy gummy precipitate to form. The benzene was decanted off and the gummy precipitate washed with benzene. The precipitate was next taken up in hot isopropyl-alcohol. On cooling, slightly yellow crystals formed. Upon air-drying they weighed 1.5 g. (m.p. 270°C.). This material was dissolved in water and treated with an excess of sodium bicarbonate. Extraction with either, and concentration of the ether extract, gave a small amount of residue which soon crystallized (m.p. 82–85°C.). The melting point after recrystallization from benzene was 89 to 90°C. It was identified as 4,4′-diaminodiphenylmethane.

DISCUSSION OF RESULTS

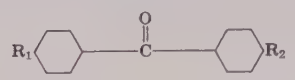
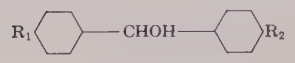
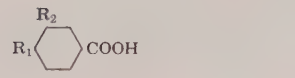
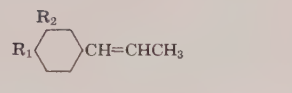
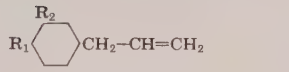
Specificity of the Reaction for the Dihydroxydiphenylmethane Group. Table I lists a number of seemingly different types of compounds which are decomposed by aniline-HCl to give the relatively simple phenols, phenol or catechol. But for one exception, all of these compounds either possess a structure of the dihydroxydiphenylmethane type, or are capable of reacting with themselves, or with the amine, to give compounds containing structures of this type. Thus, although the compounds initially differ considerably in structure, in the course of the reaction they react with themselves, or with the reagent, to give as intermediates in the decomposition reaction compounds which possess a structure of the dihydroxydiphenylmethane type.

Necessity of a Structure of the Dihydroxydiphenylmethane Type. Table II shows the results obtained on subjecting various model compounds to the action of aniline-HCl. This table reveals the following:

(a) Compounds which initially lack a structure of the dihydroxydiphenylmethane type and which are incapable of reacting with themselves, or with the reagent, to form compounds of this type are not decomposed. Examples are those compounds of series 1 to 5, where R_1 and R_2 = H. In every instance, except in the case of diphenylcarbinol (series 4), the compound was recovered almost quanitatively. In the case of diphenylcarbinol, however, almost a quantitative yield of the hydrochloride of 4-aminotriphenylmethane was obtained.

(b) Compounds which in themselves do not con-

Table II. Decomposition of Model Compounds by Aniline Hydrochloride

Series	Basic structure	Not decomposed	Decomposed
1		$R_1 = H;\ R_2 = H$ $R_1 = H;\ R_2 = OH$ $R_1 = OH;\ R_2 = OH$	...
2		$R_1 = H;\ R_2 = H$ $R_1 = H;\ R_2 = OH$	$R_1 = OH;\ R_2 = OH$
3		$R_1 = H;\ R_2 = H$	$R_1 = H;\ R_2 = OH$ $R_1 = OH;\ R_2 = OH$
4		$R_1 = H;\ R_2 = H$[a]	...
5		$R_1 = H;\ R_2 = H$[b]	...
6		$R_1 = H$[c]	$R_1 = OH$ $R_1 = OCH_3$
7		$R_1 = H;\ R_2 = H$[d]	$R_1 = OH;\ R_2 = H$ $R_1 = OH;\ R_2 = OCH_3$ $R_1 = OCH_3;\ R_2 = OCH_3$
8		$R_1 = H;\ R_2 = H$[e]	$R_1 = OH;\ R_2 = H$ $R_1 = OH;\ R_2 = OCH_3$ $R_1 = OCH_3;\ R_2 = OCH_3$
9		...	$R_1 = OH;\ R_2 = OCH_3$
10		...	$R_1 = OH;\ R_2 = OCH_3$

[a] Almost a quantitative yield of 4-aminotriphenylmethane.
[b] 85.5% yield of 1-(4-aminophenyl)-1,2-diphenylethane.
[c] 33% yield of 4-aminodiphenylmethane.
[d] 22% yield of 4,4′-diaminotriphenylmethane.
[e] 84% yield of benzanilide.

tain a structure of the dihydroxydiphenylmethane type, but which are capable of reacting with themselves, or with the amine, to form compounds of this type, are decomposed. Examples are those compounds of series 6 to 9, where R_1 = OH or OCH_3, and R_2 = OH or OCH_3. Dehydroiisoeugenol is also an example.

(c) Compounds which initially contain a structure of the dihydroxydiphenylmethane type are decomposed. Examples are dihydroxydiphenyldimethylmethane, conidendrin (Fig. 1), diisoeugenol (Fig. 4) and phenolphthalein.

Further evidence of the necessity of a structure of the dihydroxydiphenylmethane type lies in the results obtained when an amine, as triethylamine, is used instead of aniline (Table III). The nondecomposition of vanillin, dehydrodiisoeugenol, salicyl alcohol, etc., when subjected to the action of triethylamine hydrochloride can be explained on the basis that this amine lacks a reactive hydrogen; viz., a hydrogen on a benzene ring *para* to the amino group. As a consequence, it cannot react as does aniline to form a compound of the dihydroxydiphenylmethane type.

On the other hand, a material such as isoeugenol (series 9, Table II), which reacts readily with itself to form a compound of the dihydroxydiphenylmethane type, viz., diisoeugenol, decomposes when subjected either to the action of aniline-HCl or triethylamine-HCl.

The only evidence to date which appears to be against the necessity of a structure of the dihydroxydiphenylmethane type is in the decomposition of eugenol (series 10, Table II). Attempts to prepare, or isolate, an intermediate similar to that obtained with isoeugenol (i.e., diisoeugenol) were unsuccessful. The high yield of catechol (i.e., 45%) obtained suggests that this compound reacts more or less directly. Structurally eugenol consists essentially of a hydroxyphenyl group and an allyl group. The electron displacement induced by the allyl group is similar to that induced by the hydroxyphenyl group. The allyl group, in reality, thus acts as if it were another hydroxyphenyl group. The mechanism of cleavage, thus, is the same as if a structure of the dihydroxydiphenylmethane type were present.

Decomposition Mechanism When Functional Group is an Aldehyde, Alcohol or Propenyl Group. The isolation of 4,4′-diaminodiphenyldimethylmethane and of 4,4′-diaminodiphenylmethane and 4-methoxy-4′-aminodiphenylmethane in the decomposition of bisphenol-A and anisyl alcohol, respectively, when using aniline-HCl

Table III. Aniline Hydrochloride Versus Triethylamine Hydrochloride as Decomposing Agents

Compound	Decomposed by: Aniline-HCl	Decomposed by: Triethylamine-HCl
Vanillin	Yes	No
Dehydrodiisoeugenol	Yes	No
Isoeugenol	Yes	Yes
Eugenol	Yes	Yes
Diisoeugenol	Yes	Yes
Salicyl alcohol	Yes	No
Anisyl alcohol	Yes	No

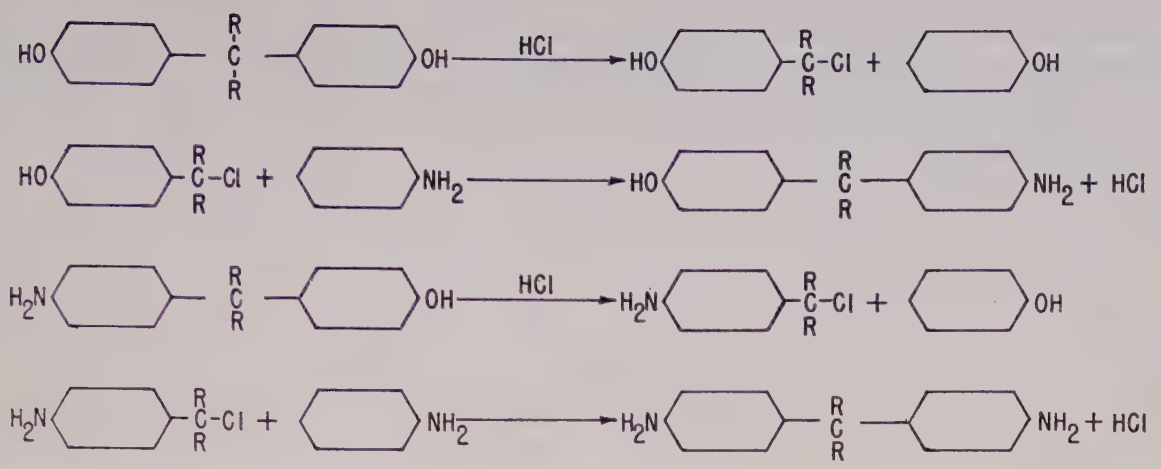


Fig. 2. General decomposition mechanism

as the decomposing reagent, suggests the general reaction mechanism shown in Fig. 2.

Such a mechanism, however, in order to apply to compounds such as vanillin, isoeugenol, requires the intermediate formation of a compound of the dihydroxydiphenylmethane type. This occurs in two ways: (1) the compound reacts with itself, or (2) the compound reacts with the amine. Vanillin is an example of the latter. It reacts with aniline to give the anil (I, Fig. 3), which in turn reacts further to give the triphenylmethane derivative (II, Fig. 3). Although the intermediate compounds I and II (Fig. 3) have not been isolated from the reaction mixture itself, 4,4′-diaminotriphenylmethane has been isolated in good yield on treatment of benzaldehyde with aniline-HCl under the

Table IV. Decomposition of Vanillin and Derivatives

Compound	Yield of catechol on treatment with, Per cent of theoretical: Aniline-HCl	Triethylamine-HCl
Vanillin	20.5	Nil
Vanillalaniline	34.8	3.1
3-Methoxy-4-hydroxy-4′,4″-diaminotriphenylmethane	32.8	11.5

decomposition reaction conditions. This, together with the actual yields of catechol obtained when compounds I and II, prepared by other means, are subjected to the action of aniline-HCl and triethylamine-HCl supports this mechanism (Table IV). Evidence that the important structure is the triphenylmethane structure (II) rather than the anil structure (I), is supported by the fact that when vanillin is treated with dimethylaniline-HCl (a compound unable to form an anil)

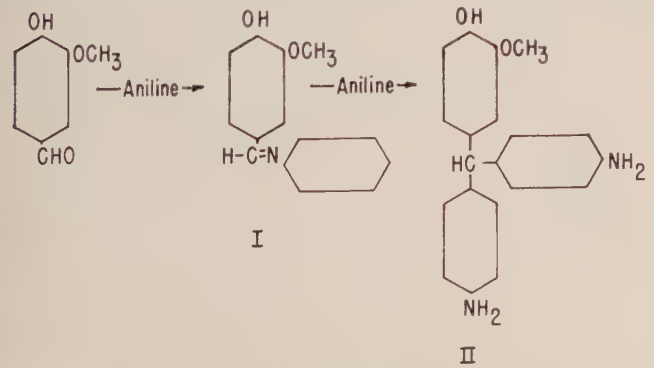


Fig. 3. Vanillin—formation of dihydroxydiphenylmethane type structure

yields of catechol are obtained similar to aniline-HCl.

Whereas vanillin reacts with the amine to give a compound of the necessary structure, isoeugenol reacts with itself to give diisoeugenol (Fig. 4). The fact, also, that diisoeugenol on treatment with either aniline-HCl or triethylamine-HCl gives catechol in high yield (Table V), supports the assumption that diiseougenol constitutes the intermediate in the decomposition of isoeugenol.

In instances where the functional group is an alcohol (i.e., salicyl alcohol, anisyl alcohol), two mechanisms appear possible. One involves the reaction of the compound with the amine (I, Fig. 5), the other, with itself, to form a compound of the phenol formaldehyde resin type (II, Fig. 5). The nondecomposition of

Table V. Decomposition of Isoeugenol and Diisoeugenol by Aniline Hydrochloride and Triethylamine Hydrochloride

Compound	Yield of catechol on treatment with, Per cent of theoretical: Aniline-HCl	Triethylamine-HCl
Isoeugenol	22.7	8.2
Diisoeugenol	54–82	32.7

salicyl and anisyl alcohols by triethylamine-HCl (Table III), supports the first mechanism. Infrared spectral analysis, however, appears to support the latter. The fact that compounds of the type shown in Fig. 6 can actually be isolated when benzyl and anisyl alcohols, respectively, are treated with aniline-HCl, lends support to the former mechanism.

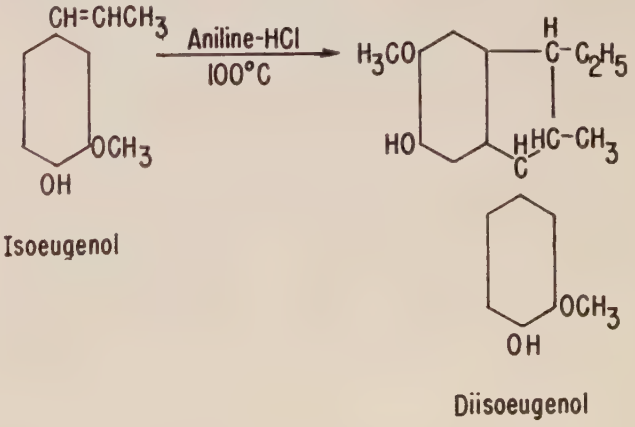
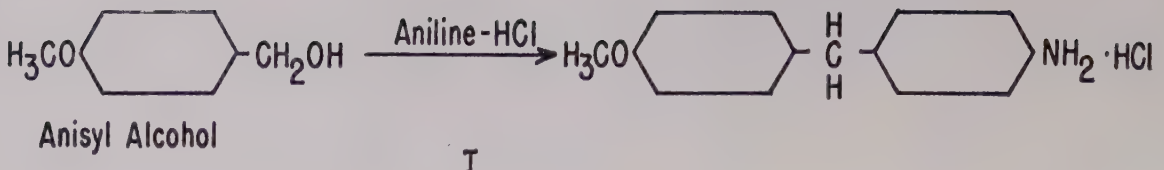
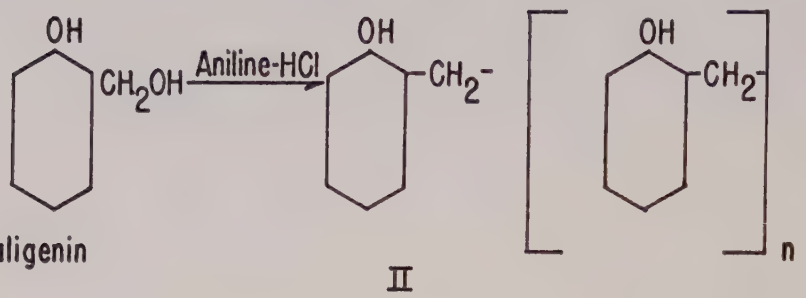


Fig. 4. Isoeugenol—formation of dihydroxydiphenylmethane structure



Anisyl Alcohol

I



Saligenin

II

Fig. 5. Formation of dihydroxydiphenylmethane type structure in case of anisyl alcohol and saligenin

The decomposition of dehydrodiisoeugenol can be explained on the assumption that the cyclic either ring is opened, and the resulting secondary alcohol group then combines with the aniline to give a compound of the required type (Fig. 7). The fact that diphenylcarbinol and 1,2-diphenylethanol, actually form compounds of the type postulated on reaction with aniline-HCl suggests that such a reaction can take place. This, together with the fact that aniline-HCl causes decomposition whereas triethylamine-HCl does not, supports such a mechanism. Attempts to prepare, or isolate, a compound of the type postulated have been unsuccessful.

Origin of Catechol on Subjecting Lignin to the Action of Aniline Hydrochloride. Experiments carried out wherein various lignins were subjected to the action of aniline-HCl, as well as to the action of triethylamine hydrochloride, indicate that only when aniline-HCl was used were there indications that an appreciable quantity (viz., 5–10%) of catechol was formed. These results, together with the results obtained with the various model compounds, suggest that the catechol must arise from a structure of one of the types shown in Fig. 8, rather than from a structure of the true dihydroxydiphenylmethane type (Fig. 1), as exemplified by diisoeugenol (Fig. 4), or conindendrin (Fig. 1).

Various investigators (*9*) have shown that when lignin reacts with a phenol new phenolic hydroxyl groups are introduced. Freudenberg (*10*) interprets this to be the result of the cleavage of open or cyclic ether linkages (Fig. 9). The condensation of phenol through its

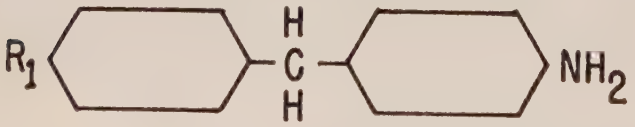


Fig. 6. R_1 = H for benzyl alcohol; R_1 = OCH_3 for anisyl alcohol

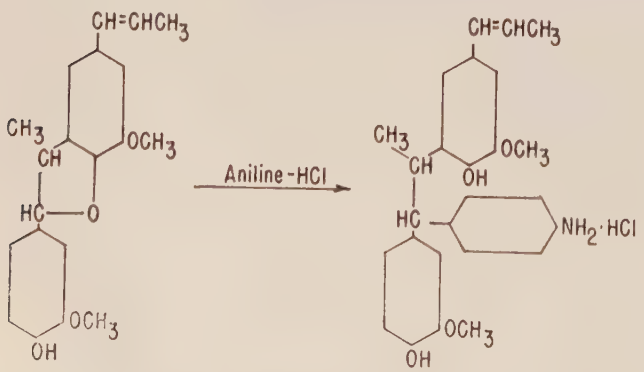
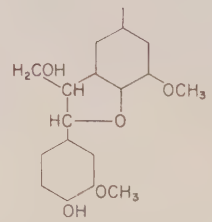
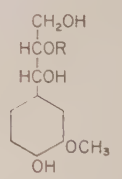


Fig. 7. Dehydrodiisoeugenol—formation of dihydroxydiphenylmethane type structure



Cyclic ether or dehydrodiisoeugenol type structure



Guaiacylglycerol type structure

Fig. 8. Types of structures which could give catechol on treatment with aniline-HCl

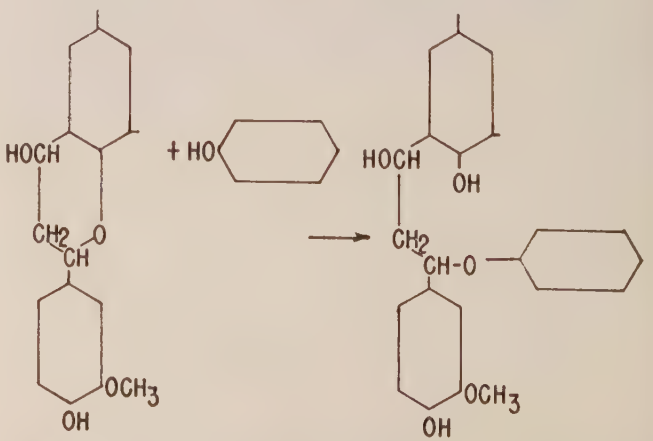


Fig. 9. Reaction of lignin with phenol according to Freudenberg

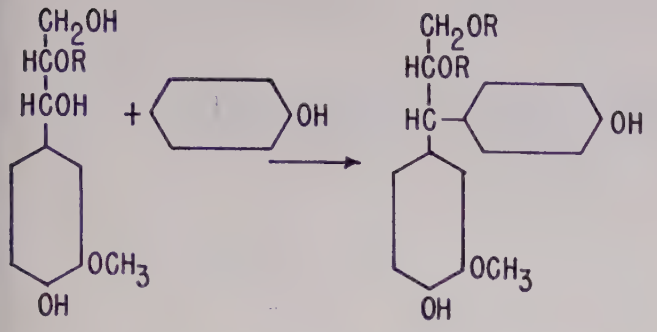


Fig. 10. Suggested reaction of phenol with lignin

para-position with the free secondary alcohol group, as occurs in the guaiacylglycerol structure, likewise would result in the appearance of a new phenolic hydroxyl group (Fig. 10).

Considerable evidence exists which suggests that a carbon-to-carbon bond may be formed. In the presence of an acid catalyst, 4-hydroxytriphenylmethane (*11*) is formed on treating diphenylcarbinol with phenol. Wedekind (*12, 13*) has suggested that the *p*-hydrogen atom of phenol reacts with a hydroxyl group in lignin. Wacek (*14*) has found small amounts of salicylic, cresylic, and 5-chlorosalicylic acids, respectively, on oxidizing phenol lignin, cresol lignin, and *p*-chlorophenol lignin with alkaline nitrobenzene. This indicates that the phenol must have formed a carbon-to-carbon linkage with at least a part of the lignin.

The similarity of many of the reactions of phenol and aniline with compounds of the type R_2CHOH (*11*) suggests that the reaction of lignin with aniline could also involve a carbon-to-carbon rather than an amino type of linkage. The formation of 4-amino-triphenylmethane and 4-amino-1,2-diphenylethane on treating, respectively, diphenylcarbinol and 1,2-diphenylethanol with aniline-HCl are examples of this. The formation, then, of the catechol which is observed

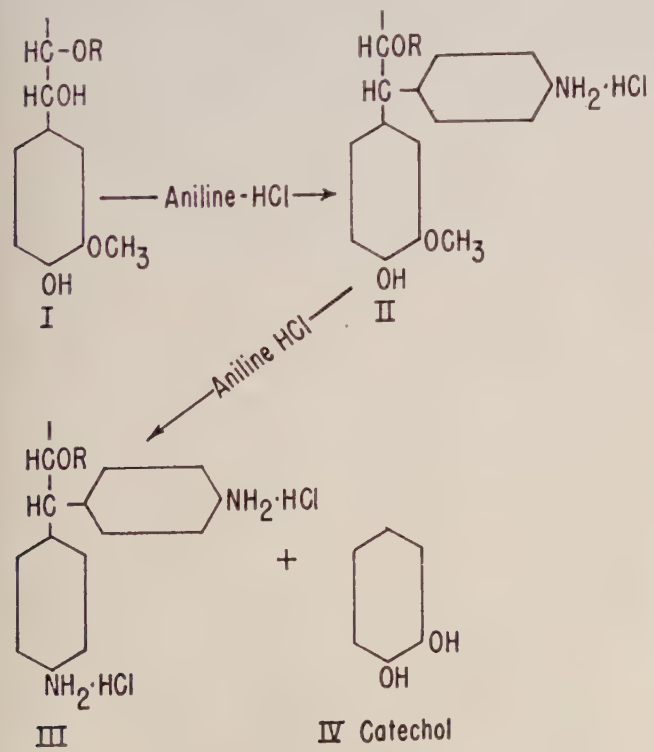


Fig. 11. Mechanism of formation of catechol from lignin

on treating lignin with aniline-HCl probably results from the condensation of the amine with the secondary alcohol group, as occurs in the guaiacylglycerol type of structure, to give a structure of the dihydroxydiphenylmethane type (II, Fig. 11). This structure, in turn, is attacked further by the amine in a manner whereby the dihydroxyphenyl group is actually displaced by an aminophenyl group. This mechanism is preferred over the mechanism which involves opening of a cyclic ether structure. The main reason is that the cyclic ether structure mechanism would require, in the case of phenol, the formation of two new hydroxyl groups for each phenolic group condensed with the lignin. Since this is not the case, and since aniline and phenol react similarly in condensations of this type, the mechanism as postulated is preferred.

SUMMARY

Compounds which possess a structure of the dihydroxydiphenylmethane type when subjected to the action of certain compounds of the type $RNH_{1-3}X$ decompose to give simple phenols. Similarly decomposed are those compounds which initially lack a structure of this type but which can, through reaction with themselves, or with the amine, form compounds possessing such a structure.

The catechol observed when lignin is subjected to the action of certain compounds of the type $RNH_{1-3}X$ probably arises from a guaiacyl-glycerol type of structure within the lignin. The structure of the dihydroxydiphenylmethane type necessary as the intermediate, arises as a result of the condensation of the amine with the free secondary alcohol group such as occurs in the guaiacylglycerol type of structure.

The results obtained imply that when phenols and amines are condensed with lignin, using an acid catalyst, a carbon-to-carbon rather than an ether or amino type of linkage is obtained. It is believed that this occurs to an extent greater than previously realized.

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The experimental work which forms the basis of this paper has been going on over a considerable period of time. About half the work was carried out in the laboratories of the Institute of Paper Chemistry, Appleton, Wis., while the author was on sabbatical leave, in 1953. The author wishes to thank Dr. Brauns, Dr. Buchanan, Dr. Kremers, Dr. Pearl, and Mr. Dickey of the Institute Staff for their interest and many helpful suggestions while working at the Institute. Thanks are also extended to Kimberly-Clark Corp., Neenah, Wis., for the sabbatical leave which made the greater part of this work possible.

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Alkaline Pulping of Small Wood Subdivisions

T. N. KLEINERT, L. M. MARRACCINI, and E. J. DOSTAL

Alkaline cooking of wood (poplar and spruce), mechanically defibrated in the presence of the liquor, has been studied in the liquid phase and also in the vapor phase after removal of the excess liquor. Solution of portions of the wood in the alkaline liquors was found to occur even below 100°C.; factors being alkali concentration, temperature, and time of reaction. Drop of pulp yield and delignification during cooking were studied and distinct mechanisms were found. Pulps from defibrated wood exhibited a higher residual lignin content and a lower carbohydrate yield than those from nondefibrated wood; these differences, were found to decrease as cooking time increased. In the whole range of alkali concentrations investigated, pulp viscosity plotted vs. carbohydrate yield exhibited a single linear relationship irrespective of the defibration of the wood. Wood defibration resulted in reduction of pulp strength properties. Soaking of wood wafers in the alkaline liquor before cooking was found to slow down delignification and to result in lower pulp yields and higher values of the residual pulp lignin.

In general, chemical pulping is considered to be a complex of topochemical reactions. This view was expressed by Jayme and Grögaard (*1*) and also by Nolan (*2*). Recently, Bucher (*3*) discussed problems arising out of the morphology of wood. The distribution of the lignin (*4*) in the structure of the wood and within the cell walls is a major influence in chemical pulping. Larocque and Maass (*5*) showed that alkaline delignification of the wood takes place at the lignin-liquor interface following adsorption of the alkali on the lignin. According to Nolan (*6*), alkaline pulping occurs at a moving interface, which penetrates into the wood as cooking proceeds. He also demonstrated that an increase in wood surface area, by appropriate methods of subdivision, results in an increased rate of delignification. On the other hand, Larocque and Maass (*7*) found that delignification proceeded at the same rate for wood meal (particle size 0.05 mm.) as for chips of 10 mm. thickness. Recently (*8*) the pressing of softwood chips in the cross-grain direction was found to crack the chips lengthwise and thus to improve penetration with kraft cooking liquor and the subsequent cooking of the wood.

The influence of particle or chip size on the quality of the resulting pulps has received considerable attention. This is a complex problem, since pulp quality is influenced not only by the cooking conditions and the size of the wood subdivisions, but also by the method used to increase wood surface. It is known that mechanical damage to the wood which occurs before pulping, as in chipping, results in a deterioration of pulp-strength properties. This is especially true in acid pulping (*9*, *10*). Jayme and Grögaard (*1*) have found that defibration of wood before kraft pulping is not as detrimental. Recently (*11*), kraft pulping of Asplund fibers was found to give poor results. When wood was subjected to compression in the axial direction prior to kraft pulping, pulps of lower strength (*12*, *13*) were produced. Mechanical treatment (*14*) of the pulp during the final stages of a kraft cook was found to affect beating and strength properties of the pulps.

As shown above, there is much evidence that mechanical damage is detrimental to pulp quality in alkaline pulping. However, there is also evidence that pulp deterioration is minimized when the wood is cut in the grain direction. This is the conclusion reached following a study (*15*) which compared the results of kraft pulping on wood in the form of both commercial spruce mill chips and spruce wafers, 1 by 1.5 by 0.021 in. When cooked under similar conditions, pulps from wafers and chips exhibited similar physical properties. In these experiments, time to temperature (170°C.) was 1.5 hr., and time at temperature was also 1.5 hr.

In cooking thin wood subdivisions, such as wafers, penetration of the cooking chemicals into the wood occurs without difficulty. To increase the wood surface and promote penetration (*2*, *6*), Nolan used shredded chips in kraft pulping, and he reported good strength properties of the resulting pulps. To promote penetration and decrease screen rejects of kraft pulps, Hartler (*16*) suggested that chip thickness be decreased. Recently, Kleinert, *et al.* (*17*), investigated alkali sorption on small wood subdivisions and also forced penetration of dilute alkali into wood. These authors found that if wood subdivisions of limited thickness ($^1/_{10}$ in.) across the grain were used, rapid and almost uniform alkali distribution was achieved throughout the wood. The present investigations deal with the rapid pulping of alkali-penetrated, small wood subdivisions.

In reviewing the literature mentioned above, a series of questions arose:

(a) To what extent does the defibration of wood in the presence of alkaline liquor before cooking affect the solution of wood portions;

(b) How does such treatment affect the chemical and physical properties of pulps produced by cooking this defibrated wood;

(c) How is the pulping rate of defibrated wood influenced by variation of liquor concentration, cooking temperature and time, and also what is the influence of these variables on cellulose viscosity.

In the following experiments, poplar as well as sprucewood was used either in form of wafers or chips. For defibration of the wafers a Waring blendor was used, whereas the wood chips were defibrated in a 12-in. Sprout-Waldron refiner. The total amount of alkali initially present in the wood in vapor-phase cooking was adjusted according to the different lignin contents of hardwoods and softwoods.

MECHANICAL DEFIBRATION OF WOOD IN ALKALINE LIQUORS

In earlier investigations (*17*) of alkali sorption on

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Table I. Solubility of Mechanically Defibrated Poplarwood in Sodium Hydroxide Solutions of Varying Concentration

Lignin content of the wood, 19.05%; reaction temperature, 20°C.

Liquor conc.	Retention time, min.	Soluble portions: Total,[a] %	Lignin,[a] %	Hemicellulose, %	Lignin calcd. on initial, %	Lignin in insoluble residue, %
1% NaOH	10	8.0	2.4	5.6	12.6	18.1
	20	9.7	3.0	6.7	15.6	17.8
	40	10.5	3.4	7.1	17.7	17.7
	60	10.6	3.1	7.5	16.5	17.8
2% NaOH	10	13.6	3.7	9.9	19.2	18.0
	20	13.6	3.4	10.2	17.9	18.1
	40	14.0	3.6	10.5	18.7	18.0
	60	14.2	3.7	10.6	19.3	17.9
3% NaOH	10	15.7	3.5	12.3	18.2	18.5
	20	17.1	3.5	13.6	18.3	18.5
	40	17.6	3.7	13.9	19.5	18.6
	60	18.1	3.8	14.3	19.9	18.6
4% NaOH	10	18.6	3.5	15.1	18.2	19.1
	20	19.4	3.6	15.8	18.8	19.2
	40	19.8	3.8	16.0	19.9	19.0
	60	19.9	3.7	16.2	19.0	19.1

[a] Based on ovendry wood.

small wood subdivisions, solution of a portion of the wood was observed even with short reaction time at temperatures below 100°C. This effect was increased when the mechanical subdivision of the wood was achieved in the presence of the alkaline liquors. Obviously, solubilization of some of the wood material must have occurred right from the start of defibration.

To study this, wood shavings (poplar and spruce) were soaked for 5 min. in the alkaline liquor (wood-to-liquor ratio 1:20), and subsequently defibrated in presence of the liquor. Defibration of the wood and removal of the fiber slurry to the reaction vessel took a total of 5 min.; retention time was the additional time of reaction of the alkali in the fiber slurry. Sodium hydroxide concentrations of 1 to 4% at 20, 60, and 100° C. with retention time varying from 10 to 60 min. were studied. The results obtained are presented in Tables I, II, and III.

The tables show that the amount of total substance dissolved from the wood in the alkaline fiber slurry is dependent upon the sodium hydroxide concentration, the reaction temperature, and the reaction time. As sodium hydroxide concentration is increased to 4%, the

Table II. Solubility of Mechanically Defibrated Poplar wood in Sodium Hydroxide Solutions of Varying Concentration

Lignin content of the wood, 19.05%; reaction temperature, 60°C.

Liquor conc.	Retention time min.	Soluble portions: Total,[a] %	Lignin,[a] %	Hemicellulose, %	Lignin calcd. on initial, %	Lignin in insoluble residue, %
1% NaOH	10	11.2	2.7	8.5	14.2	18.4
	20	11.8	2.9	8.7	15.4	18.3
	40	12.5	2.9	9.7	15.1	18.5
	60	12.7	3.3	9.5	17.2	18.1
2% NaOH	10	15.3	3.0	12.3	15.8	18.9
	20	15.5	3.2	12.3	16.9	18.8
	40	15.5	3.2	12.3	16.7	18.8
	60	16.5	3.5	12.9	18.6	18.5
3% NaOH	10	16.9	3.0	13.8	15.9	19.3
	20	17.2	3.3	13.9	17.1	19.1
	40	18.4	3.4	15.1	17.6	19.3
	60	19.4	3.5	16.0	18.1	19.4
4% NaOH	10	20.3	3.3	17.0	17.5	19.9
	20	20.2	3.4	16.8	17.6	19.7
	40	20.6	3.4	17.3	17.6	19.7
	60	20.6	3.6	17.1	18.7	19.5

[a] Based on ovendry wood.

Table III. Solubility of Mechanically Defibrated Poplarwood in Sodium Hydroxide Solutions of Varying Concentration

Lignin content of the wood, 19.05%; reaction temperature, 100°C.

Liquor concn.	Retention time, min.	Soluble portions: Total,[a] %	Lignin,[a] %	Hemicellulose, %	Lignin calcd. on initial, %	Lignin in insoluble residue, %
1% NaOH	10	12.4	3.9	8.5	20.4	17.3
	20	12.9	3.9	9.0	20.4	17.4
	40	15.2	4.3	10.8	22.6	18.8
	60	15.6	4.5	11.1	23.8	17.1
2% NaOH	10	15.2	3.9	11.4	20.4	17.9
	20	18.0	4.4	13.5	23.4	17.8
	40	18.0	4.5	13.6	23.5	17.8
	60	18.5	4.4	14.1	23.0	18.0
3% NaOH	10	19.2	3.6	15.6	18.9	18.9
	20	19.5	3.9	15.6	20.5	18.8
	40	20.8	4.0	16.8	21.0	19.0
	60	22.9	4.4	18.5	23.1	19.0
4% NaOH	10	22.2	4.0	18.2	20.7	19.4
	20	22.8	3.9	19.0	20.2	19.7
	40	24.8	4.1	20.8	21.5	19.9
	60	24.8	4.2	20.6	22.2	19.7

[a] Based on ovendry wood.

solubility of the hemicelluloses increases appreciably, whereas that of the lignin increases only slightly. These findings substantiate those obtained earlier by Hellström (*18*) in a study of the solubility of birchwood in alkali.

In another series of experiments, spruce wafers were mechanically defibrated at 20 and 100°C. in kraft cooking liquor of commercial composition (3.5% NaOH + 1.0% Na_2S), and after various times of reaction, the residues, their lignin content, and the cupriethylenediamine (CED) viscosities of the chlorite holocelluloses were determined, using TAPPI Standard T 230 sm-50. The extractives were then hydrolyzed with sulfuric acid and the resulting sugars were estimated chromatographically. The amounts of sugars were expressed as percentages of the total carbohydrates dissolved (Tables IV and V). The balance of the carbohydrates consisted of uronic acids and galactose.

Tables IV and V show that temperature is a major factor in the dissolution of portions of the wood by kraft liquor. Whereas at 20°C. a reaction time longer than 30 min. does not noticeably affect the total amount of wood portions dissolved, at 100°C. dissolving proceeds as the reaction time increases, although a levelling off after 120 min. is indicated. Compared with poplar-

Table IV. Mechanical Defibration of Sprucewood in Kraft Cooking Liquor

Wood-to-liquor ratio, 1:20; lignin content of the initial wood, 28.3%; reaction temperature, 20°C.

	Retention time, min. 30	60	90	120
Insoluble residue, %	94.7	94.9	94.0	94.2
Dissolved portions, %	5.3	5.1	6.0	5.8
Klason-lignin, % of residue	28.6	28.4	28.2	27.8
Klason-lignin, % (calcd. on ovendry wood)	27.1	27.0	26.5	26.2
CED viscosity (0.5% Holocellulose[a]), cp.	21.0	24.1	22.9	20.1
Sugars in hydrolyzed extractives, % of total carbohydrates				
Glucose	7	16	11	17
Mannose	14	10	22	21
Arabinose	9	16	11	8
Xylose	22	31	33	29

[a] Determined by TAPPI Standard T 9 m-51.

Table V. Mechanical Defibration of Sprucewood in Kraft Cooking Liquor

Wood-to-liquor ratio, 1:20; lignin content of the initial wood, 28.3%; reaction temperature. 100°C.

	Retention time, min.			
	30	60	90	120
Insoluble residue, %	90.9	85.0	82.4	81.2
Dissolved portions, %	9.1	15.0	17.6	18.8
Klason-lignin, % of residue	28.5	29.5	30.0	30.1
Klason lignin, % (calcd. on ovendry wood)	25.9	25.0	24.7	24.4
CED viscosity (0.5% holocellulose,[a]) cp.	36.8	39.2	38.7	46.7
Sugars in hydrolyzed extractives (% of total carbohydrates)				
Glucose	5	11	25	31
Mannose	8	7	...	21
Arabinose	12	19	25	15
Xylose	35	34	25	28

[a] Determined by TAPPI Standard T 9 m-51.

wood, less lignin was removed from spruce by the alkaline treatment. From the data of the hydrolysis sugars it appears that hemicelluloses which yield pentoses on hydrolysis are extracted first from the wood, whereas those giving glucose and mannose, in increasing amounts as the time of reaction increases. This is in accordance with earlier findings of Schuerch, *et al.* (*19*), who have shown that pentosans can be extracted in high yield from woodmeal of various wood species by a single-stage extraction at 80 to 100°C. Since there might be some intermolecular rearrangement of the carbohydrates in the alkaline medium, particularly at extended reaction time, the estimated distribution of the sugars after hydrolysis gives merely a general indication of the nature of these carbohydrates.

ALKALINE COOKING OF DEFIBRATED AND NONDEFIBRATED WOOD IN LIQUID PHASE

It has been claimed by Nolan (*6*) that increasing the wood surface by subdivision results in a faster pulping rate. On the other hand, within a certain range of sizes of wood subdivisions, Larocque and Maass (*7*) noticed no influence on delignification. To study this discrepancy, wood wafers mechanically defibrated in the presence of sodium hydroxide solutions of increasing concentration, as well as nondefibrated wood wafers were cooked at 180°C. in the alkaline liquors. In order to maintain an approximately constant sodium hydroxide concentration throughout the cook, a high liquor-to-wood ratio (50:1) was used. The cooks were carried out in stainless steel bombs heated at constant temperatures in an oil bath. The effect of variation of cooking time on pulp yield, residual pulp lignin and pulp viscosity was studied. The tosylchloroamide consumption (*20*) (TSCA) of the pulps was taken as a measure of the residual lignin.

Table VI presents the cooking results of poplar wafers mechanically defibrated in sodium hydroxide solutions of 1 to 4% NaOH content and for comparison, the corresponding data obtained with nondefibrated wood wafers. Table VII shows the results of liquid-phase cooking of defibrated poplar wafers at 190°C. in solutions of 1 to 6% NaOH. In all digestions the wood was cooked immediately after soaking in the liquor.

The results of the cooks at 180°C. are also presented in Figs. 1 and 2. It can be seen that the yields of the pulps from nondefibrated and defibrated poplarwood

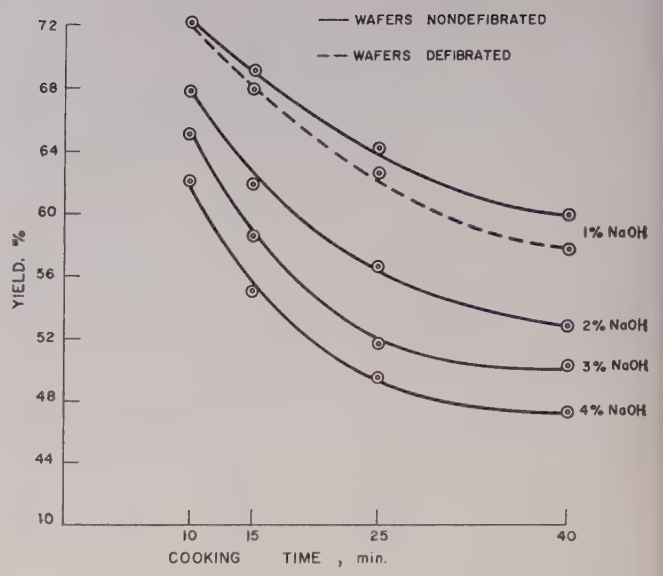

Fig. 1. Pulp yields of defibrated and nondefibrated poplar wafers cooked at 180°C. with variation of sodium hydroxide concentration (1–4%) and of cooking time

cooked in solutions of 2 to 4% NaOH are the same; whereas in the cooking with 1% NaOH solution the yields obtained from the defibrated wood were somewhat lower than those from the nondefibrated wood. At this low sodium hydroxide concentration, the influence of the increased accessibility of the wood by defibration is noticeable. For cooking times up to 25 min., the residual lignin content of the pulps obtained from defibrated wafers was higher and the carbohydrate yield lower than that from nondefibrated wafers (Table VI). When viscosity was plotted versus carbohydrate yield, practically a single linear relationship was found whether the wood was defibrated before cooking or

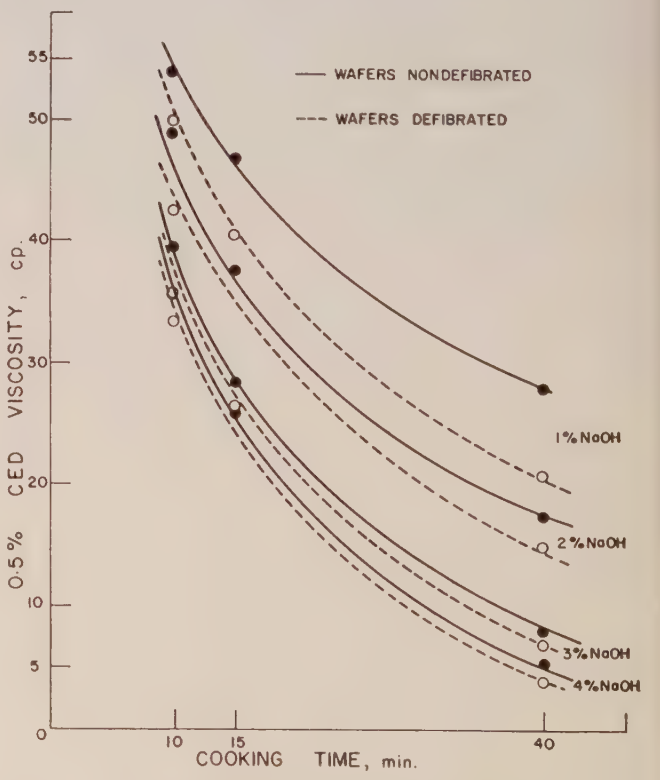

Fig. 2. Pulp viscosity of defibrated and nondefibrated poplar wafers cooked at 180°C. with variation of sodium hydroxide concentration (1–4%) and of cooking time

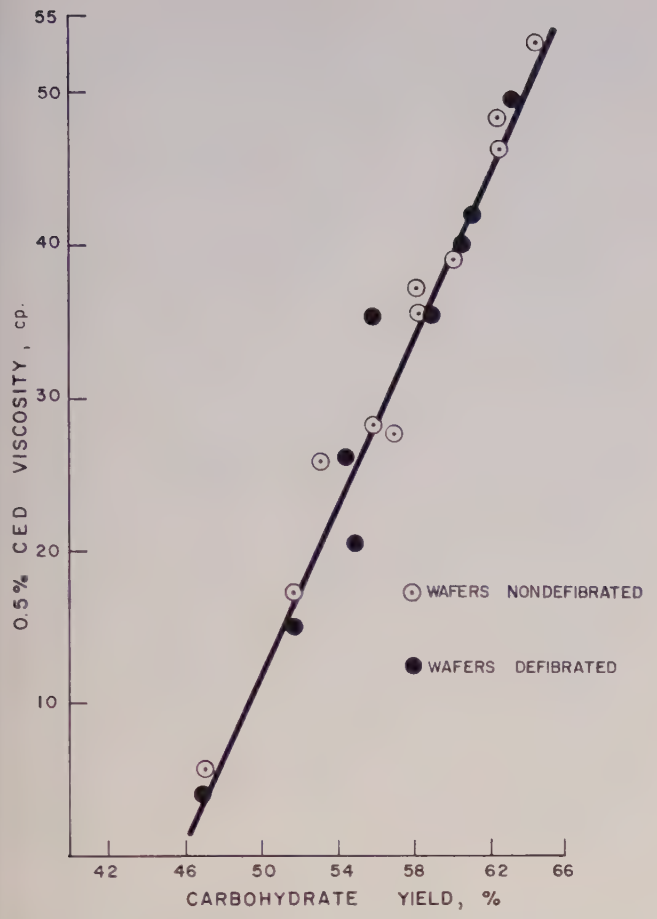

Fig. 3. Pulp viscosity vs. carbohydrate yield in cooking (180°C.) of defibrated and nondefibrated poplar wafers

not (Fig. 3). This finding is an indication that the mechanical defibration used in our experiments did not noticeably affect the cellulose at the molecular level. When the residual pulp lignin of nondefibrated poplar wafers was plotted against pulp yield, a curve was obtained exhibiting a pronounced curvature in the low-yield range below about 52% (Fig. 4).

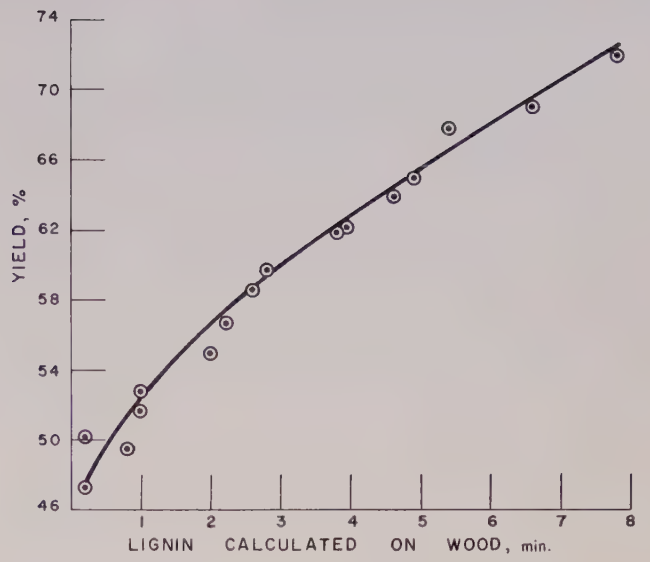

Fig. 4. Residual lignin vs. yield of pulps from nondefibrated poplar wafers

Figure 5, shows the delignification of defibrated poplar wafers in liquid-phase cooking (Table VII) for different cooking times as a function of the sodium hydroxide concentration of the cooking liquor. As can be seen, the 1% residual-lignin level of the resulting pulps is reached with the 2% NaOH solution in about 30 min., with the 3% liquor in about 20 min., and with the 4% liquor in about 15 min. After reaching this lignin content, delignification levels off in all three cases.

Tables I to V show that appreciable portions of mechanically defibrated wood are dissolved when in contact with alkaline liquors. Increases in the sodium hydroxide concentration, the temperature and the time of reaction promote this solution. These phenomena apply also to the reaction of kraft cooking liquors of commercial composition with wood at temperatures below 100°C. (*17*), as shown earlier. There remained to be studied the influence of the duration of

Table VI. Liquid-Phase Cooking with Variation of Cooking Time of Poplar Wafers, Nondefibrated (NDF) and Defibrated (DF), in Sodium Hydroxide Solutions of Varying Concentrations.

Wood-to-liquor ratio, 1:50; Reaction temperature, 180°C.

NaOH conc.	*Cooking time, min.* 10 NDF	10 DF	15 NDF	15 DF	25 NDF	25 DF	40 NDF	40 DF
1% NaOH								
Total yield, %	72.2	72.3	69.1	68.0	64.0	62.6	59.8	57.7
Pulp lignin, %	10.8	12.6	9.6	11.1	7.2	8.5	4.7	4.8
Lignin (calcd. on o.d. wood), %	7.8	9.1	6.6	7.5	4.6	5.3	2.8	2.8
Carbohydrate yield, %	64.4	63.2	62.5	60.5	59.4	57.3	57.0	54.9
0.5% CED viscosity, cp.	53.8	49.9	46.7	40.4	...	...	28.0	20.7
2% NaOH								
Total yield, %	67.2	68.6	62.3	61.5	57.0	56.3	52.7	52.9
Pulp lignin, %	7.9	10.0	6.1	7.5	3.9	4.6	2.0	2.1
Lignin (calcd. on o.d. wood), %	5.3	6.9	3.8	4.6	2.2	2.6	1.0	1.1
Carbohydrate yield, %	62.6	61.7	58.5	56.9	54.8	53.7	51.7	51.8
0.5% CED viscosity, cp.	48.9	42.5	37.6	...	...	...	17.4	15.0
3% NaOH								
Total yield, %	64.5	65.7	58.2	59.0	51.6	51.7	50.6	49.8
Pulp lignin, %	7.5	9.5	4.4	7.2	2.0	2.6	0.4	0.3
Lignin (calcd. on o.d. wood), %	4.8	6.2	2.6	4.2	1.0	1.3	0.2	0.2
Carbohydrate yield, %	59.7	59.5	55.6	54.8	50.6	50.4	50.4	49.6
0.5% CED viscosity, cp.	39.6	35.8	28.6	26.3	...	...	8.2	7.0
4% NaOH								
Total yield, %	61.5	62.7	54.6	55.4	49.4	49.6	47.3	47.1
Pulp lignin, %	6.2	10.2	3.6	7.0	1.6	2.0	0.4	0.4
Lignin (calcd. on o.d. wood), %	3.8	6.4	2.0	3.9	0.8	1.0	0.2	0.2
Carbohydrate yield, %	57.7	56.3	52.6	51.5	48.6	48.6	47.1	46.9
0.5% CED viscosity, cp.	35.8	33.1	26.0	...	...	...	5.5	4.0

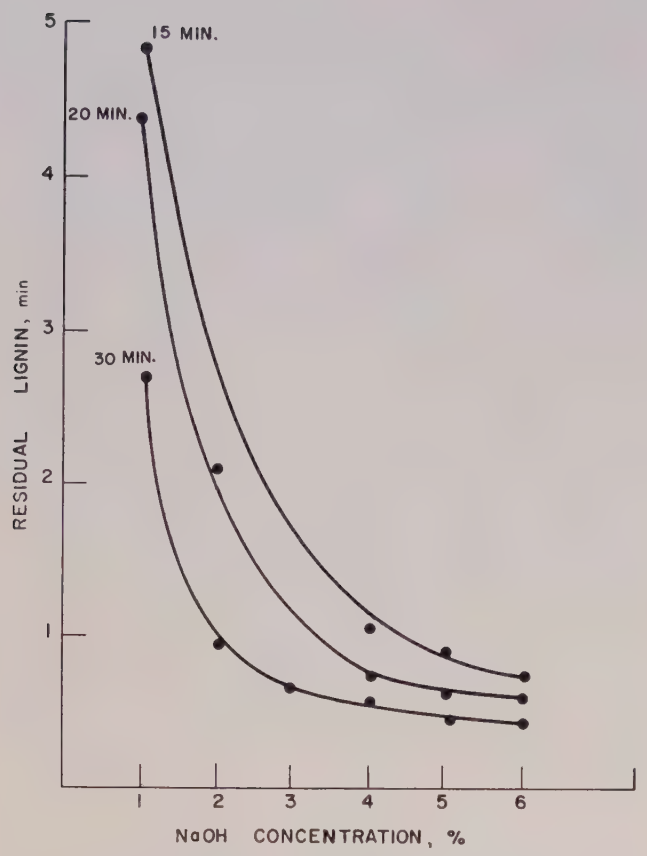

Fig. 5. Residual lignin vs. sodium hydroxide concentration of pulps cooked at 190°C. from defibrated poplar wafers

partial alkaline extraction of the wood and of the liquor temperature on the subsequent kraft cooking.

A series of cooks of sprucewood mechanically defibrated in the presence of kraft cooking liquor (wood-to-liquor ratio 1:20) was carried out after soaking the alkaline fiber slurry before cooking either at 20 or 100°C. for 30, 60, or 90 min. The cooking liquor contained 3.5% NaOH and 1% Na_2S. The liquor, after extraction, was removed by pressing and the residual wood was slurried in fresh cooking liquor at a ratio of 1:50. The cooking temperature was 180°C., and the cooking times were 15 and 30 min. The results obtained are presented in Table VIII. This table shows that with 15 min. cooking time, an increase in the temperature of alkaline extraction results in an increase in both the pulp yield and the residual pulp lignin; whereas an increase in the time of extraction at either 20 or 100°C. reduces the pulp yield and also the residual lignin. However, with 30-min. cooking time, resulting in appreciably lower pulp yield, the yield decreases with increasing extraction time at both temperatures, but the residual lignin, calculated on wood, increases slightly. In general, these findings show that alkaline extraction of the wood before kraft cooking affects delignification and also the carbohydrate yield.

ALKALINE COOKING OF DEFIBRATED WOOD IN THE VAPOR PHASE

In liquid-phase cooking the liquor-to-wood ratio is at least 3–4:1 and heating takes place by direct heat transfer from liquor to wood. Rapid heating of the wood to a predetermined cooking temperature is

Table VII. Liquid-Phase Cooking with Variation of the Cooking Time of Mechanically Defibrated Poplar Wafers in Sodium Hydroxide Solutions of Varying Concentrations

Wood-to-liquor ratio, 1:50; reaction temperature, 190°C.

NaOH concn.	*Cooking time, min.* 15	20	30
1% NaOH			
Total yield, %	63.9	60.9	56.8
TSCA, % Cl	4.05	3.64	2.26
Pulp lignin, %	4.86	4.37	2.71
Carbohydrate yield, %	60.8	58.2	55.3
2% NaOH			
Total yield, %	56.7	53.5	50.0
TSCA, % Cl	2.25	1.76	0.78
Pulp lignin, %	2.70	2.11	0.94
Carbohydrate yield, %	55.1	52.4	49.5
3% NaOH			
Total yield, %	51.2	49.3	46.3
TSCA, % Cl	1.38	0.86	0.54
Pulp lignin, %	1.66	1.03	0.65
Carbohydrate yield, %	50.3	48.8	46.0
4% NaOH			
Total yield, %	48.8	46.9	43.8
TSCA, % Cl	0.89	0.60	0.47
Pulp lignin, %	1.06	0.72	0.57
Carbohydrate yield, %	48.3	46.6	43.5
5% NaOH			
Total yield, %	46.9	45.1	41.9
TSCA, % Cl	0.70	0.51	0.38
Pulp lignin, %	0.84	0.61	0.45
Carbohydrate yield, %	46.5	44.8	41.7
6% NaOH			
Total yield, %	45.5	44.0	40.7
TSCA, % Cl	0.60	0.46	0.35
Pulp lignin, %	0.72	0.55	0.42
Carbohydrate yield, %	45.1	43.8	40.5

difficult because of the high liquor-to-wood ratio. In vapor-phase cooking, on the other hand, heating of the chemical-penetrated wood material occurs by condensation of steam. The amount of residual penetration liquor held by the defibrated wood material can be adjusted by appropriate methods such as centrifuging or pressing.

Table IX presents data of the weight increase and the amount of sodium hydroxide retained by poplar wood which was defibrated in a Waring Blendor in the presence of solutions of sodium hydroxide of various concentrations, and subsequently centrifuged under conditions standardized at 5 min. and 100 g.

Compared with the weight increase of poplar chips treated under the same conditions (found experimentally to be about 150%) the weight increase of defibrated poplarwood was appreciably higher due to the larger wood surface. Table IX also shows that with increasing sodium hydroxide concentration of the liquor there is an increased alkali retention. The strong retention and the high weight increase found with the 7%

Table VIII. Kraft Cooking of Extracted, Mechanically Defibrated Sprucewood

Extraction time, min.	*Pulp yield, %* 15	30	*Klason-lignin, %* 15	30	*Residual lignin, % on wood* 15	30
			Cooking time, 15 and 30 min.			
			20°C.[a]			
30	53.3	42.1	16.2	3.10	8.7	1.30
60	52.7	41.8	15.8	3.16	8.3	1.32
90	51.8	41.8	15.1	3.33	7.8	1.39
			100°C.[a]			
30	55.3	41.4	18.5	3.34	10.2	1.38
60	54.6	40.8	17.7	3.76	9.7	1.53

[a] Temperature of extraction.

Table IX. Defibration of Poplar Wafers in Solutions of Sodium Hydroxide of Various Concentrations; Alkali-Retention after Centrifuging

NaOH concn. of liquor, %	*Weight increase[a] after centrifuging, %*	*NaOH retained,[a] %*
3.0	334.7	12.1
4.0	344.4	16.0
5.0	348.4	19.6
6.0	340.5	23.5
7.0	410.2	32.3

[a] Calculated on ovendry residue.

NaOH solution is probably due to a pronounced swelling effect.

To study delignification in the vapor phase, mechanically (Waring Blendor) defibrated poplar wafers of various sodium hydroxide contents were subjected to cooking in saturated steam at 175 and 180°C. Pulp yield and residual lignin were determined for 20 and 30-min. cooking times. In these experiments about 100 g. of wood was used. The results obtained are presented in Table X.

Table X. Vapor-Phase Cooking of Defibrated, NaOH-Penetrated Poplar Wafers

Total alkali,[a] %NaOH	*Cooking temp., °C*	*Cooking time — 20 min — Yield, %*	*20 min — Lignin, %*	*30 min — Yield, %*	*30 min — Lignin, %*
12.1	175	63.4	11.8	61.0	10.0
16.0	175	59.3	8.1	57.8	7.2
19.6	175	57.0	6.2	54.9	5.0
23.5	175	54.4	4.4	52.6	3.5
32.3	175	51.8	2.9	50.6	2.6
12.1	180	59.6	9.2	58.5	8.6
16.0	180	56.2	6.4	54.6	5.2
19.6	180	53.4	4.2	51.8	3.1
23.5	180	50.9	2.6	49.9	2.0
32.5	180	48.9	1.6	48.0	1.3

[a] Calculated on ovendry residue.

Just as in liquid-phase cooking, the rate of delignification increases with increasing alkali content of the wood. Compared with the corresponding data of Table VI, the yield as well as the residual lignin increases noticeably; probably this is related to the lower residual alkali present at the end of the vapor-phase cooks.

In another series of experiments, vapor-phase kraft cooking of small wood subdivisions in a 2-cu. ft. digester was investigated. This served the purpose of producing pulps in amounts sufficiently large for physical testing. In particular, the cooks were designed to compare pulping of nondefibrated poplar- and spruce wafers on the one hand, and poplar and spruce mill chips on the other. The latter were first de-aerated, then pressure-penetrated with the liquor (at 70°C.), and subsequently defibrated in presence of the liquor in a 12-in. Sprout-Waldron refiner. From cold caustic soda pulping, it is known that in presence of alkaline liquor the power consumption for defibration is considerably reduced and also that a fairly uniform alkali distribution within the wood can be achieved. Before cooking, the excess of penetration liquor was removed from the wood material by centrifuging under standardized conditions in such a way as to retain in the poplar-wood about 16% NaOH and in the sprucewood about 22.5% NaOH, according to the different lignin content of these wood species. Vapor-phase cooking of the pretreated wood was carried out at 185°C. with variation of the cooking time. The cooking temperature was reached within 3 min. Table XI presents the chemical and physical data (at 300 ml. C.S.f.) of the pulps from nondefibrated (NDF) and defibrated (DF) poplar- and sprucewood.

Table XI. Vapor-Phase Kraft Cooking (185°C.) of Nondefibrated (NDF) and Defibrated (DF) Poplar- and Sprucewood

Wood	*Cooking time, min.*	*Pulp yield, % NDF*	*DF*	*Pulp lignin, % NDF*	*DF*	*Breaking length, km. NDF*	*DF*	*Tear factor, g./g.s.m. NDF*	*DF*
Poplar	5	55.8	53.7	4.0	8.1	11.6	8.7	71	54
(16%	7	...	51.4	...	6.8	...	9.4	..	57
NaOH)	10	54.1	50.3	2.2	5.5	11.9	8.6	72	57
	15	54.1	47.8	2.1	4.1	12.0	8.4	75	58
	20	...	45.6	...	3.7	...	8.0	..	57
Spruce	10	...	57.7	...	13.1	....	11.2	..	52
(22.5%	15	52.2	51.4	6.7	10.6	14.4	11.2	97	62
NaOH)	17	...	50.9	...	10.3	...	11.3	..	65
	18.5	...	50.2	...	9.7	...	11.4	..	71
	20	51.0	49.9	5.6	9.2	14.7	11.3	92	67

It appears that defibration of penetrated wood chips results in pulps of lower yield and higher lignin content than those from nondefibrated wood. However, also the time of reaction of the alkali on the wood before cooking has a bearing. This, for instance, can be seen

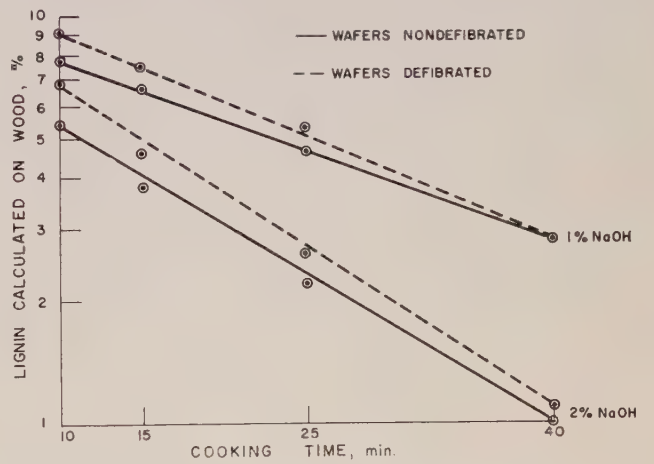

Fig. 6. Delignification of defibrated and nondefibrated poplar wafers with increasing cooking time

when comparing the poplar cooks with 16% NaOH content of the wood (Tables X and XI). Although, there is a 5°C. difference in the cooking temperature, the time interval which elapsed between the defibration of the penetrated wood chips (about 12 lb.) in the disk mill and the cooking of the wood material was essentially longer (about 2 hr.) than that required for the preparing of the wafer samples (about 10 g.), which took only about 20 min. Possibly, the longer time of reaction of the alkali on the wood is responsible for the difference in pulp yield and residual lignin.

The defibration of the wood before kraft cooking results also in a considerably lower breaking length (in poplar by 28%, in spruce by 24%) as well as a lower tear factor (poplar 22%, spruce 33%). Therefore, it is concluded that mechanical damage of the wood before cooking is detrimental not only in acid sulfite pulping,

but also in alkaline pulping. The relatively higher strength data of the pulps from defibrated sprucewood observed in our experiments in comparison with those obtained earlier by Jayme and Grögaard (*1*) are possibly related to the shorter cooking time used in our investigations.

INFLUENCE OF PRESOAKING TIME

As seen from the results of the work involving the defibrating of wood in the presence of alkaline liquors at room temperature (20°C.) or elevated temperature (100°C.), there is a rapid dissolving of easily accessible hemicellulose portions, especially those containing pentosans, uronic acids, etc.; but relatively small amounts of lignin are removed. Although tempera-

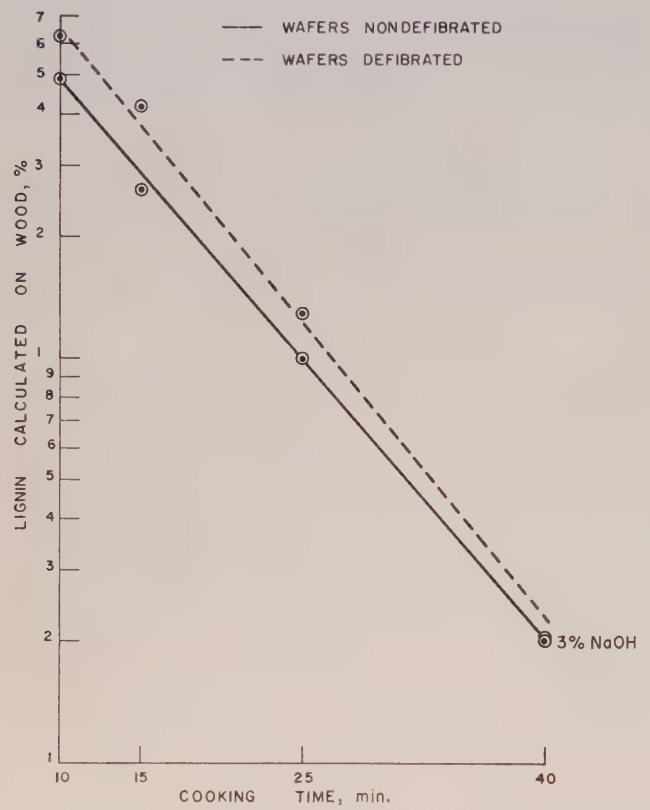

Fig. 7. Delignification of defibrated and nondefibrated poplar wafers with increasing cooking time

ture is a minor factor in the sorption of alkali on wood, as shown earlier by Lusby and Maass (*27*), it influences the solubility of certain hemicelluloses.

Our experimental results show that defibration of wood in alkaline liquors results not only in a partial extraction of easily accessible carbohydrates, but affects delignification in a way which decreases the pulp carbohydrate yield and increases the residual lignin. Therefore the time of soaking of the wood in the alkaline liquor before cooking might have an influence. This was studied experimentally.

Black spruce wafers were soaked at room temperature in kraft liquor (3.5% NaOH + 1% Na_2S) in a ratio of 1:30. The wood material was treated for different times; it was then cooked in the same liquor under varying conditions of temperature and time. The results are presented in Table XII.

The experimental data show clearly that longer soak-

Table XII. Kraft Cooking of Spruce Wafers with Variation of the Soaking Time

Pulp data	*Soaking time, hr.* 0	48	72	120
25 min. cooking at 175°C.				
Pulp yield, %	50.0	50.8	...	49.7
Pulp lignin, %	11.6	14.1	...	14.9
Pulp lignin (calcd. on oven-dry wood), %	5.8	7.2	...	7.4
Carbohydrate yield, %	44.2	43.6	...	42.3
15 min. cooking at 181°C.				
Pulp yield, %	52.4	...	51.7	...
Pulp lignin, %	14.2	...	15.6	...
Pulp lignin (calcd. on oven-dry wood), %	7.4	...	8.1	...
Carbohydrate yield, %	45.0	...	43.6	...

ing of the wood in the alkaline liquor before cooking increases the residual lignin, calculated on wood, whereas the carbohydrate yield drops. This finding opens an interesting question: whether the extended reaction of the wood with alkali during the soaking

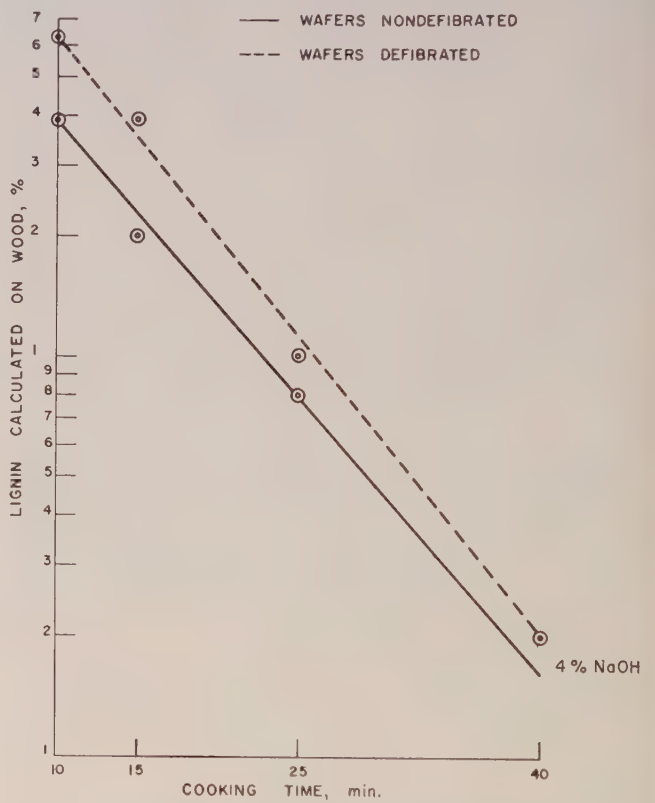

Fig. 8. Delignification of defibrated and nondefibrated poplar wafers with increasing cooking time

changes the macromolecular configuration of the lignin (*28*) in a way which affects delignification.

KRAFT COOKING OF COTTON

At the relatively high temperature used in commercial kraft cooking, the pulp cellulose is attacked by alkali, especially in the later stages of cooking. This results in loss of pulp yield and a decrease in pulp viscosity. Two distinct mechanisms of the degradative action of hot sodium hydroxide solutions on cellulose are known: the peeling-off effect which starts at the reducing end groups, (*21–24*) and random chain scission (*25, 26*) along the molecule. As shown by

Corbett and Richards (*26*), the latter is due neither to oxidation nor to thermal degradation, but to the action of the hydroxyl ions alone. In contrast to the peeling-off degradation of cellulose, which results in yield loss without decreasing cellulose viscosity to any great extent, the random chain scission is the main cause of the viscosity drop of cellulosic materials when treated with hot alkali. However, Samuelson and Wennerblom (*23*) found that chain breakage results in solution of about 50 chain units, and therefore also in yield loss.

To elucidate the influence of hot alkali on undegraded cellulose under the conditions of alkaline pulping of wood, short-time kraft cooking of untreated cotton was studied in a series of experiments. In particular, vapor-phase cooking of California cotton soaked with different amounts of kraft cooking liquor was compared with liquid-phase cooking of the cotton, using a liquor containing 3.5% NaOH plus 1.0% Na_2S. Two series of vapor-phase cooks were carried out with cotton-to-liquor ratios of 1:1.5 and 1:5. In the liquid-phase cooks a cotton-to-liquor ratio 1:50 was used, in order to provide good liquor circulation, and to maintain approximately a constant alkali concentration throughout the cooking. The time of cooking was varied between 15 and 45 min. The cooking temperature in the vapor-phase cooks was 185°C., in the liquid-phase cooks 180°C. The changes in cellulose yield and CED viscosity (0.5%) are shown in Table XIII.

Table XIII. Kraft Cooking of Untreated Cotton (CED Viscosity 334)

Cook	Cooking Temp., °C.	Cooking Time, min.	Yield, %	CED Viscosity (0.5%), cp.
Vapor-phase: Cotton-to-liquor, 1:1.5	185	15	92.0	153
	185	30	92.0	97
	185	45	91.8	83
Vapor-phase: Cotton-to-liquor, 1:5	185	15	91.7	210
	185	30	91.9	203
	185	45	91.4	162
Liquid-phase: Cotton-to-liquor, 1:50	180	15	90.2	28.5
	180	30	86.7	11.9
	180	45	84.0	5.9

The table shows that for equal cooking times yield and viscosity dropped less in vapor-phase cooking at 185°C. than in liquid-phase cooking at 180°C. When using the lowest liquor-to-cotton ratio (1.5:1) in vapor-phase cooking the yield drop was lowest. However, the viscosity data obtained in this cook series are lower than those obtained in vapor-phase cooking at the same temperature with a liquor-to-cotton ratio of 5:1. In the series of vapor-phase cooks carried out in a liquor-to-cotton ratio of 1.5:1, the pH after cooking was reduced by the neutralization of acidic substances (*26*) formed in the cellulose degradation. This is an indication that in vapor-phase kraft cooking a minimum amount of alkali must remain in the pulp material in order to prevent cellulose degradation.

It is interesting to note that in the liquid-phase cooking a large viscosity decrease happens concurrently with a sharp yield drop, indicating increased chain splitting. The latter may be attributed to the fact that the cellulose was directly exposed to a large excess of the hot alkali and that the alkali concentration throughout the cooking was close to the initial concentration. The experiments seem to indicate that short-time vapor-phase kraft cooking degrades cellulose relatively little, if an appropriate alkalinity is used.

CONCLUSIONS

The investigations show that alkaline liquors extract from small wood subdivisions, even at room temperature, certain portions of the wood. These phenomena are influenced mainly by the alkali concentration, but temperature and reaction time are also factors. There are considerable differences in the amounts of portions dissolved from both poplar and sprucewood defibrated in presence of the alkaline liquor under similar conditions. More hemicelluloses and lignin are removed from the hardwood.

The cooking experiments show that the drop in pulp yield follows approximately an exponential function, as if it were related to desorption phenomena. An almost straight-line relationship was found when plotting yield versus cooking time on a log-log scale. In contrast, delignification exhibited a similar relationship only on semilog scale (Figs. 6–8). Comparative cooking, to the same yield, of defibrated and nondefibrated wood shows that defibration increases the residual pulp lignin. This is in accordance with recent findings of Lauer, *et al.* (*29*), in which the kraft pulping of sawdust resulted in a high lignin content of the pulps. By defibration of the wood in the alkaline liquor, the solid–liquid interface is increased promoting removal of soluble portions. However, as shown, delignification of defibrated wood is rather slowed down; this is pronounced when the time of the alkaline pretreatment of the wood before cooking is extended. Thus, and also by the loss of certain wood constituents, the macromolecular structure and the properties of the lignin might have been changed. Further investigations are being carried out to study this problem.

Commercially interesting is our finding that the strength properties of pulps produced under the same cooking conditions from defibrated wood are appreciably lower than those from nondefibrated wafers. On the other hand, defibration of the wood is not a factor in the viscosity drop if the carbohydrate yield is considered. This indicates that deterioration of pulp strength properties during alkaline cooking of defibrated wood is caused by other phenomena than a mechanical shortening of cellulose chains.

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Errata

In the article, "The Structure of Paper," *Tappi* 43, No. 9: 737–752 (September, 1960), the following errors have been indicated by the authors.

Page 739, line 1, dimension of l, mm., *not* cm.; line 38, $p(r)$ = Fraction of 1-sq. mm. squares containing r fibers; line 36, r = Number of fibers in square of area a. Equation (3) should read

$$r(g) = \frac{N}{L} \exp\left(-\frac{N}{L} g\right) dg \qquad (3)$$

Pages 740–741, Table I: equation (4a) should read

$$M = \frac{A\bar{r}\pi}{2}\left(\frac{N}{L}\right) \qquad (4a)$$

The numerical values of M are 23940, 24530, 18870, and 17440. Equation (7) should read

$$\bar{n}_g = \bar{c} \exp\left(-\frac{\pi\tilde{\omega}\bar{c}\bar{r}^2}{2\bar{\lambda}}\right)$$

The numerical values of $\bar{n}_g$ are 12.7, 13.1, and 6.6. Equation (7a) should read

$$\bar{n}_g = \left(\frac{\bar{\lambda}}{\bar{r}}\right)\left(\frac{N}{L}\right) \exp\left(-\frac{\pi\tilde{\omega}N\bar{r}}{2L}\right) \qquad (7a)$$

Equation (8a) should read

$$g = \frac{L}{N} \qquad (8a)$$

(All values of N_h are $\times 10^5$.)

Page 742, line 4; Fiber length of sheet no. 3 = 0.178 cm. Equation (20) should read

$$m(n_c) = \frac{2[\exp(-\bar{n}_{seg})]\,\bar{n}_{seg}^{\,1/2}(1+\sqrt{1+8n_c/P'})}{\sqrt{P'(P'+8n_c)}\;\;[1/2\,(1+\sqrt{1+8n_c/P'})]!}\, dn_c \qquad (20)$$

Equation (21) should read

$$P' = \frac{\pi\bar{n}_f\bar{r}^2(\bar{k}-1)^2}{8\bar{k}(\bar{n}_f\bar{k}-\bar{r}^2)} \qquad (21)$$

Column 2, line 19, omit "the differential form of" from "into the differential form of equation (23). This . . ." Equation (24) should read

$$n(n_g) = \sum_{i=1}^{\infty} \frac{\left[\exp\left(-\frac{N\lambda_i}{L\bar{r}}\right)\right]\left(\frac{N\lambda_i}{L\bar{r}}\right)^{n_g \exp\left(\frac{\pi\tilde{\omega}\bar{r}N}{2L}\right)}}{\left[\exp\left(-\frac{\pi\tilde{\omega}\bar{r}N}{2L}\right)\right]\left(n_g \exp\left\{\frac{\pi\tilde{\omega}\bar{r}N}{2L}\right\}\right)!}\;\phi(\lambda_i) \qquad (24)$$

Page 743, the histogram in Fig. 3b is the incorrect one for this pulp. We did not make one for it, but only measured $\bar{\lambda}$, which is 1.78 mm.

Page 746, Table III: The data for sheet no. 3 for this table was calculated on the basis of $\bar{\lambda}$ = 0.178 cm. Equation (A18) should be (A17). The following numerical values for sheet no. 3 are incorrect: no. 3, exptl., 4.52; no. 5, exptl., 0.46; no. 12, calcd., 1.5×10^{-5}**

Page 748, Table IV: Column heading no. 4, "Mean fiber weight per unit length (g./mm. $\times 10^7$)"; no. 7, mean fiber weight per unit length = 2.0, not 2.3; no. 8, mean fiber length = 1.78 mm., not 2.27.

Page 750: Equation (A4) should read

$$N_h' = {}^1/_2N'(N'+1) = {}^1/_2N'^2 \text{ (when } N' \gg 1) \qquad (A4)$$

First column, second line from bottom should read "when $1 \gg \pi\tilde{\omega}/2L$ . . ." Equation following (A11) should read

$$\bar{n}_g = N \exp\left(-\frac{N_f\bar{\alpha}}{A}\right)$$

Equation (7) should read

$$\bar{n}_g = \bar{c} \exp\left(-\frac{\pi\tilde{\omega}\bar{r}^2\bar{c}}{2\bar{\lambda}}\right) \qquad (7)$$

Equation following (9) should read

$$\bar{a}_h = \frac{A}{N_c - N_f}$$

Page 751: Equation below equation (A16) should read

$$\overline{\lambda^2_{ch}} = l^2[ln\,(1+\sqrt{2}) + {}^1/_3\,(1-\sqrt{2})]$$

Equation (21) should read

$$P' = \frac{\pi\,\bar{n}_f\bar{r}^2(\bar{k}-1)^2}{8(\bar{n}_f\bar{k}-\bar{r}^2)\bar{k}}$$

In the paper "Infrared Spectra of Crystalline Polysaccharides: VII. Thin Wood Sections," by C. Y. Liang, K. H. Bassett, E. A. McGinnes, and R. H. Marchessault, *Tappi* 43, No. 12: 1017 (1960), the captions for Figs. 3 and 4 are interchanged. These should read:

Fig. 3. Polarized infrared spectra of wood radial sections: (A) western red cedar in KBr disk. (B) red maple in KBr disk. (C) Douglas-fir in trace of Nujol

Solid curve: electric vector perpendicular to fiber axis. Broken curve: electric vector parallel to fiber axis.

Fig. 4. Infrared spectra of wood cross-setions (A) and radial sections (B). (C) Infrared spectrum of wood powder from white spruce in KBr disk

Solid curve: western red cedar. Broken curve with triple dots: red maple. Broken curve with single dot: western hemlock. All the sections were in KBr disks.

ASSOCIATION NEWS AND EVENTS

National Conferences

1961

Lignin Symposium, Aug. 14–16, 1961, Edgewater Beach Hotel, Chicago, Ill.

Twelfth Testing Conference, Aug. 15–18, 1961, Queen Elizabeth Hotel, Montreal, Que.

Eleventh Corrugated Containers Conference, Sept. 6–8, 1961, St. Francis Hotel, San Francisco, Calif.

Fourth International Mechanical Pulping Conference, Sept. 19–21, 1961, Edgewater Beach Hotel, Chicago, Ill.

6th Deinking Conference, Oct. 4–6, 1961, Hotel Harris, Kalamazoo, Mich.

Sixteenth Plastics-Paper Conference, Oct. 9–11, 1961, French Lick Sheraton Hotel, French Lick, Ind.

Sixteenth Engineering Conference, Oct. 15–19, 1961, Shoreham, Hotel, Washington, D. C.

Fifteenth Alkaline Pulping Conference, Nov. 1–3, 1961, Rice Hotel, Houston, Tex.

1962

47th Annual Meeting, Feb. 18–22, 1962, Commodore Hotel, New York, N. Y.

Thirteenth Coating Conference, May 14–16, 1962, Netherland-Hilton Hotel, Cincinnati, Ohio.

Thirteenth Testing Conference, Sept. 18–20, 1962, Benjamin Franklin Hotel, Philadelphia, Pa.

Seventeenth Plastics-Paper Conference, Oct. 8–11, 1962, Statler-Hilton Hotel, Boston, Mass.

Seventeenth Engineering Conference, Oct. 14–19, 1962, Queen Elizabeth Hotel, Montreal, Que.

Twelfth Corrugated Containers Conference, Oct. 23–26, 1962, Statler-Hilton Hotel, Boston, Mass.

Sixteenth Alkaline Pulping Conference, Oct. 31, Nov. 1–2, 1962, DeSoto Hotel, Savannah, Ga.

1963

Fourteenth Coating Conference, May 19–22, 1963, Concord Hotel, Kiamesha Lake, N. Y.

Thirteenth Corrugated Containers Conference, Oct. 22–25, 1963, Statler-Hilton Hotel, Detroit, Mich.

Eighteenth Engineering Conference, Oct. 28–31, 1963, Netherland-Hilton Hotel, Cincinnati, Ohio.

Other Associations

Study Group of European TAPPI Members, Annual Meeting, June 12–15, 1961, Bruxelles, Belgium.

Zellcheming, June 27–30, 1961, Annual Meeting, Baden-Baden, Germany.

International Union of Pure and Applied Chemistry (IUPAC), Aug. 6–12, 1961, Annual Meeting, Montreal, Que.

Technical Section of the British Paper and Board Makers' Association, Sept. 25–29, 1961, Symposium: The Formation and Structure of Paper, Oxford, England.

Papirindustriens Tekniske Forening, Dec. 5–6, 1961, Technical Convention, Oslo, Norway.

Ink Receptivity Meeting

The Subcommittee on Ink Receptivity of the Graphic Arts Committee of the Coating and Graphic Arts Division of the Technical Association of the Pulp and Paper Industry, held a meeting on March 22 at Lehigh University to discuss recent progress of the work being carried out on there under the sponsorship of TAPPI. The meeting was conducted by the Subcommittee Chairman, W. C. Walker, West Virgina Pulp & Paper Co., Williamsburg, Pa. H. Maxwell Hughson, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., was at the same time welcomed as a new member on the subcommittee. Mr. Hughson will be representing the Coating Committee in his new appointment.

Mexican A.T.C.P.

The Association Mexicana de Tecnicos de las Industrias de la Celulosa y del Papel A.C. which was organized in August, 1960, continues as a very thriving organization under the presidency of Adalberto Tirado A. of Loreto y Pena Pobre.

On Jan. 27, 1961, a dinner meeting was held at the Club de Industriales in Mexico City and attended by 44 members. The speaker was Ake Frey, delegate of the Finnish Government in Mexico. Mr. Frey showed an interesting film, featuring the pulp and paper industry in Finland.

The February 24th meeting was held at the Instituto Mexicano de Investigaciones Tecnologicas and was attended by 75 members of the association. A visit was made to the unit-operations laboratory and especially to the pilot plant that has been erected to study the digestion, bleaching, and the preparation of cooking liquor to manufacture sulfite pulp from tropical woods. General director Ignacio Deschamps and Yannick Villegas, head of the cellulose and paper sections, presented some results of the research in this field.

At the March 24 meeting, 75 members attended a technical session at the Club de Industriales. Dante Sandro Cusi, president of Cia. Industrial de San Cristobal S.A. gave an excellent paper, describing the properties and behavior of sugarcane bagasse as a raw material for paper manufacture. A guest of honor Lic. Placido Garcia Reynoso, Sub-Secretary of Industry and Commerce of the Mexican Government was present and agreed to be the main speaker at the forthcoming annual meeting. At this meeting the Camara Nacional de las Industrias del Papel announced that it would contribute 36,000 pesos ($2900 U. S. currency) to the financial support of A.T.C.P. each year.

On April 21 and 22 a visit was made to the plant of Celanese Mexicana in Zacaper, about 200 miles from Mexico City. An interesting conference was also held.

Bound Volume—Technical Section 1960 TAPPI

Each year the pages of the Technical Section of *Tappi* are accumulated and bound in a cloth cover as a single volume. These volumes are usually ordered by members in advance. There are some copies of the 1960 volume available at $5.00 per copy and may be obtained from the Technical Association of the Pulp and Paper Industry, 360 Lexington Ave., New York 17, N. Y.

The annual meeting of A.T.C.P. was held at Hotel El Presidente in Mexico City on May 25–27. About 40 papers were presented. A tour was made of the mills of San Rafael Pulp and Paper Co. More details of this meeting will be reported in a later issue.

Indian Productivity Team

The National Productivity Council of the Government of India has sponsored a productivity team to study the paper industry in several countries. The team will leave India in June to proceed to Japan. From there it will go to Hawaii to study bagasse utilization. Visits will be made to paper mills, research laboratories, converting plants, and paper machinery plants in Mexico, Canada, and the United States. The team will be in the United States in August and will proceed to England and Sweden.

Seventh Annual Pulp and Paper Industry Electrical Engineering Conference

The Seventh Annual Conference on Electrical Engineering as Applied to the Pulp and Paper Industry will be held June 21–23, 1961, in the Auditorium of the McCracken Hall on the extensive campus of the Western Michigan University. This conference is attended by some 160 ranking electrical engineers from the mills and allied industries from widespread areas and will include mill electrical engineers from as far north as Canada and as far south as Florida.

An interesting program of technical papers and timely addresses will be directed at the improvement of technical operations in pulp and paper mills.

The annual conference on Electrical Engineering as Applied to the Pulp and Paper Industry is sponsored by the Pulp and Paper Industry Subcommittee of the American Institute of Electrical Engineers and is usually held on the campus of leading colleges and universities throughout the country.

The conference this year is being held at the University of Western Michigan. The program promises a wide variety of technical papers to be presented by leading electrical engineers from the mills and associated industries.

Advance copies are not available; however, a conference booklet containing copies of all papers to be presented will be available at the time of registration.

J. M. Yarbrough, of The Mead Corp., Chillicothe, Ohio, is chairman of the AIEE Paper and Pulp Industry Subcommittee. C. L. Eletson, Hopper Paper Co., Taylorsville, Ill., is vice-chairman and John S. Kirkland, Rome, Ga., is secretary.

Inspection trips to nearby industrial sites are being planned. A program will be included for any ladies who may be present with tentative plans including visits Thursday, June 22, to Upjohn Co.'s pharmaceutical plant, Gibson's, Inc., makers of fine stringed musical instruments, and on Friday, June 23, the ladies may make a tour of Frontenac Winery, Paw Paw.

PROGRAM

Wednesday, June 21, 1961

Afternoon Sessions

Noon	Joint Committee Luncheon—President's Dining Room. Pulp & Paper Subcommittee AIEE, Electrical Engineering Committee, Canadian Pulp & Paper Association, Faculty Lounge, Student Center, Western Michigan University.
1:30 p.m.	AIEE Pulp & Paper Subcommittee Meeting—Faculty Lounge, Student Center, Western Michigan University.
1:30 p.m.	Electrical Engineering Committee, Canadian Pulp & Paper Association, President's Dining Room, Student Center, Western Michigan University.
6:00 p.m. to 9:00 p.m.	Preregistration—Lobby, Zimmerman Hall (dormitory), Western Michigan University.

Thursday, June 22, 1961

Morning Sessions

7:30 a.m. to 8:30 a.m.	Breakfast—Dining Room, Student Center, Western Michigan University.
8:30 a.m.	Registration—Paper Technology Auditorium, McCracken Hall, Western Michigan University.
9:30 a.m.	Conference Opening—Paper Technology Auditorium, McCracken Hall, Western Michigan University. D. B. Gearhart, conference chairman, Pulp & Paper Subcommittee, presiding.
9:30 a.m.	Address of Welcome—Dr. George E. Kohrman, Dean, School of Applied Arts & Sciences, Western Michigan University. Dr. John Fanselow, Head, Department Pulp & Paper Technology, Western Michigan University. Technical Program—N. L. Heberer, presiding.
10:00 a.m.	Opening Remarks—J. M. Yarbrough, chairman, Pulp & Paper Subcommittee.
10:10 a.m.	"Engineering Developments in Papermaking"—Dr. Robert Diehm, Western Michigan University.
10:45 a.m.	Coffee Break
11:00 a.m.	Data Processing Seminar—chairman, C. A. Fletchinger, I. P., Pine Bluff. "Techniques in Data Logging"—R. P. Derrick, Westinghouse, "System Components and Assembly"—W. Mikelson, General Electric, "Applications—L. C. Crowder, St. Regis, Jacksonville.
12:30 p.m.	Luncheon—University Student Center, Western Michigan University. Chairman: W. L. Sherwood, chairman, Western Michigan Section AIEE, Consumers Power Co., Grand Rapids. Speaker: Dr. Ward Harrison, president, Allied Paper Corp., Kalamazoo.

Afternoon Sessions

	Paper Technology Auditorium, McCracken Hall, Western Michigan University.
2:15 p.m.	Presiding: C. L. Eletson, Hopper Paper Co. "Boiler Flame-Out Control"—P. K. Ryder, Electronics Corp. of America.
3:00 p.m.	Group photograph taken
3:10 p.m.	"The Application of Instantaneous-Trip Circuit Breakers in Motor Control Centers,"—W. F. Huette, Allen-Bradley Co.
5:00 p.m.	Assemble—Lobby, Zimmerman Hall. Transportation to social hour (Ladies included).
5:30 p.m. to 6:30 p.m.	Social hour
6:30 p.m.	Assemble for transportation back to University.
7:00 p.m.	Banquet—University Student Center, Ballroom. Toastmaster: A. A. Southon, retired chairman of the Board and Director Emeritus, K.V.P. Sutherland Co., Kalamazoo. Speaker: Rice Kello, zone manager, Investors Division Services, Evansville, Ind.

Friday, June 23, 1961

7:30 a.m. to 8:30 a.m.	Breakfast—Dining Room, Student Center, Western Michigan University.

Morning Sessions

	Paper Technology Auditorium, McCracken Hall, Western Michigan University
9:30 a.m.	D.C. Motor and Generator Insulation. Panel Moderator: J. S. Kirkland, Rome Kraft Co.—Panel Members: J. Ewing, Reliance Elec. & Engr. Co.; P. T. Schuerman, General Electric Co.; A. G. Posluszny, Westinghouse Electric Corp.; W. Stiffler, Olin Mathieson Co.; H. Murdock, Allis-Chalmers Co.
11:45 a.m.	Adjourn
12:15 p.m.	Lunch—Dining Room, Student Center, Western Michigan University.

Afternoon Tours

1:15 p.m.	Mill Tours 1. Sutherland Division, K.V.P. Sutherland Co., to see: Paperboard making. Carton converting.

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LADIES PROGRAM

Thursday, June 22, 1961

9:45 a.m. Visit Upjohn Co., Portage plant—one of the largest pharmaceutical plants in the world.
12:30 p.m. Lunch—Schensul's Cafeteria, Kalamazoo.
2:00 p.m. Visit Gibson's, Inc.—Makers of fine stringed musical instruments, known all over the world.
5:00 p.m. Assemble—Lobby, Zimmerman Hall for transportation to Social Hour, followed by banquet.

Friday, June 23, 1961

9:30 a.m. Tour of Frontenac Winery, Paw Paw.
12:15 p.m. Lunch—University Student Center

ADMINISTRATIVE OFFICERS—WESTERN MICHIGAN UNIVERSITY

Dr. James W. Miller, president, Western Michigan University.
Dr. George E. Kohrman, dean, School of Applied Arts & Sciences, Western Michigan University.
Dr. John R. Fanselow, head, Department of Paper Technology, Western Michigan University.
Otto Yntema, director, Division of Field Services, Western Michigan University.

University of Maine Summer Institute

The University of Maine is pleased to announce the following technical program for the First Session of the Summer Institute for the Pulp and Paper Industry scheduled for July 10–27, 1961. This program includes fundamentals of pulp technology and stresses new pulping processes, recovery, bleaching, and pulp mill costs and management. All topics are to be presented by experts from industry or recognized teachers. Although the enrollment to date is encouraging there is ample opportunity for applicants for this session.

Topic	*Lecturer*
Production of Pulp and Paper	J. C. W. Evans Editor, *Paper Trade Journal*
Forest Management	Professor Harold Young University of Maine
Structure of Wood	Professor Fay Hyland University of Maine
Chemistry of Cellulose and Lignin	Professor Irwin Douglass University of Maine
Wood Preparation—The Wood Room	N. P. Wardwell Carthage Machine Co.
Acid Pulping—Acid Preparation	Professor L. C. Jenness University of Maine
Acid Pulping—Cooking and Recovery	W. D. Kerr Fraser Co., Ltd.
Alkaline Pulping	To be selected
Recovery Units	V. P. Owens Combustion Engineering Inc.
Mechanical Pulping	Professor Fred O'Neil Syracuse University
Semichemical Pulping	R. W. Doe West Virginia Pulp & Paper
Pulp Screening and Cleaning	Representative Improved Machinery Co.
Bleaching	Professor H. Rapson University of Toronto
Pulping Process Costs	F. G. Perry, Jr. A. D. Little, Inc.
Pulp Mill Management Panel	W. H. Chisholm, president Oxford Paper Co. R. H. Cutting, president Keyes Fibre Co. M. C. McDonald, president Great Northern Paper Co.

Twelfth TAPPI Testing Conference

The Twelfth Testing Conference of TAPPI being held in Montreal, Quebec, August 15–17, is jointly sponsored by the Technical Section, CPPA. Outstanding features of the three-day meeting are a symposium on International Standardization, a technical session completely devoted to Newsprint Testing and a seminar on Microanalytical Techniques.

Dr. Lennart Stockman, director of The Central Laboratories of the Swedish Cellulose Industry, willl discuss the SCAN Methods and their adoption by the Scandinavian countries. Also featured in the symposium on International Standardization will be Miss Karin Wilson, chairman of ICCA, who will speak on the Program and Achievements of ICCA. ICCA is holding its annual meeting in Montreal on Monday, August 14, immediately prior to the Testing Conference. Dr. Waldemar Jensen, managing director of the Finnish Pulp and Paper Research Institute, will tell of the Organizations active in the field of international standardization of pulp and paper analysis and testing. Dr. Robert B. Hobbs, chief, Paper Section of the National Bureau of Standards, who is also chairman of the U. S. Advisory Committee for International Standardization, will chair the symposium.

The Seminar on Microanalytical Techniques will be of particular interest to paper industry men from the United States because of the need for determination of extremely small amounts of material in paper in connection with the 1958 Food Additives Amendment. The seminar will consist of presentations describing some of these methods and their possible applications by experts in each particular field.

Newsprint testing has long been important in Canada. The technical session devoted to Newsprint Testing will be of real interest to the industry.

The technical program, as developed by J. E. Tasman, Pulp and Paper Research Institute of Canada, Montreal, Que., is as follows:

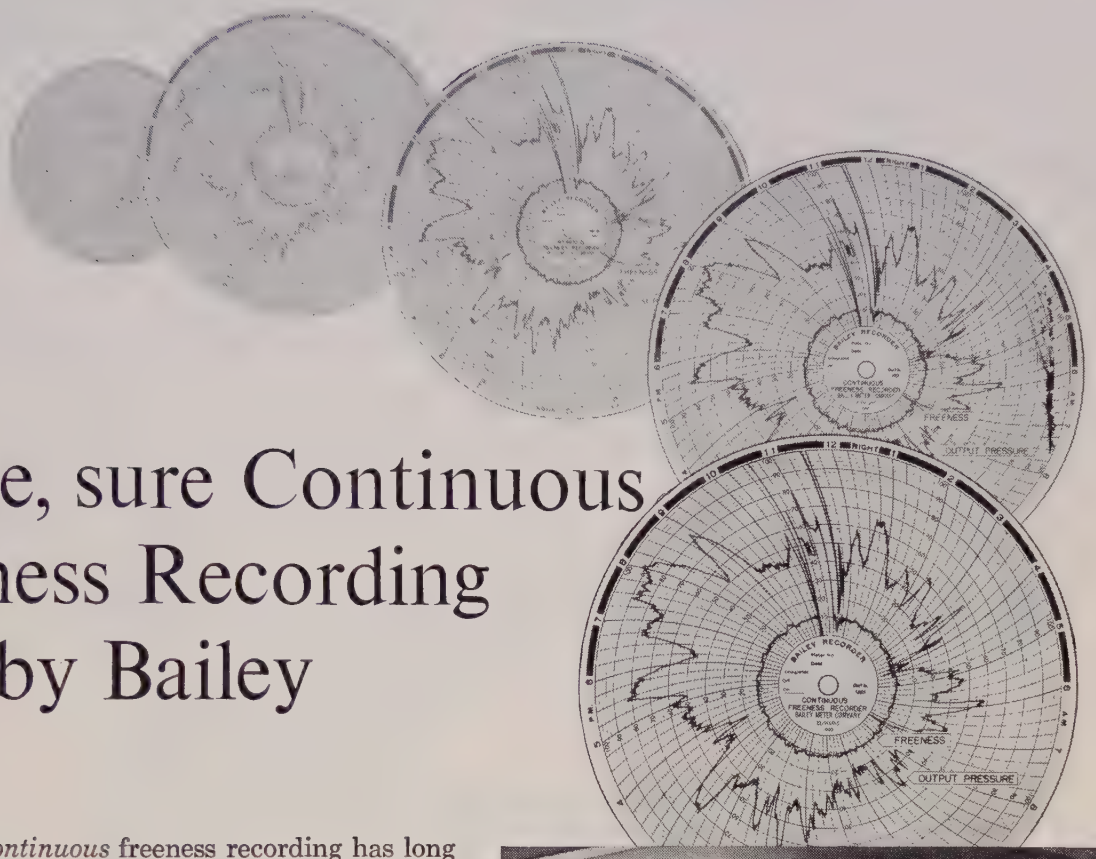
1. "The Relation of Formation to the Printability of Newsprint," by C. A. Sankey and ANPA.
2. "Physical Properties and Pressroom Running Performance," by G. Larocque, The New York *Daily News*.
3. "Newsprint Quality Control," by V. DeFelice, St. Croix Paper Co.
4. "Radioactive Tracers for Microanalysis in the Paper Industry," by F. J. Domingues, General Measurements Inc.
5. "Dispersant Requirements of Titanium Dioxide," by W. R. Willets, Titanium Pigment Corp.
6. "Particle Size Distribution of Pigment," by A. C. Dreshfield, The Glidden Co.
7. "Water Vapor Transfer Through Multiple Barriers," by K. W. Ninnemann, Olin Mathieson Chemical Corp.
8. "Determination of Calcium and Magnesium by Flame Spectrophotometry," by C. S. Joyce, Pulp and Paper Research Institute of Canada.
9. "Organizations Active in the Field of Pulp and Paper Analysis," by Prof. W. Jensen, chairman ISO/TC6/SC5.
10. "The International Committee of Cellulose Analysis," by Miss Karin Wilson, chairman ICCA.
11. "The SCAN Testing Committee," by L. Stockman, The Central Laboratory of the Swedish Cellulose Industry.

An outstanding exhibit of testing instruments has been arranged by W. F. Bachelder of Testing Machines, Inc., exhibits chairman of the conference. The following companies will exhibit equipment:

Hunter Associates Laboratory, Inc.
Emerson Apparatus Co.
Manufacturers Engineering & Equipment Corp.
Williams Apparatus Co., Inc.
Instron Engineering Corp.
Thwing-Albert Instrument Co.
Testing Machines, Inc.
The Robert Mitchel Co., Ltd. (Montreal).
Measurement Engineering, Ltd. (Ontario).

There are many mills in the vicinity of Montreal, as the map illustrates, and all have cordially opened their doors to visitors from the Testing Conference. On the way to the conference on Monday, August 14, conferees may wish to visit the mills of the E. B. Eddy Co. at Hull, Que., or the Howard Smith Paper Mills, Ltd., at Cornwall, Ont. Stopover privileges are offered by both the railroads and airlines.

Now...proved in continuous operation...



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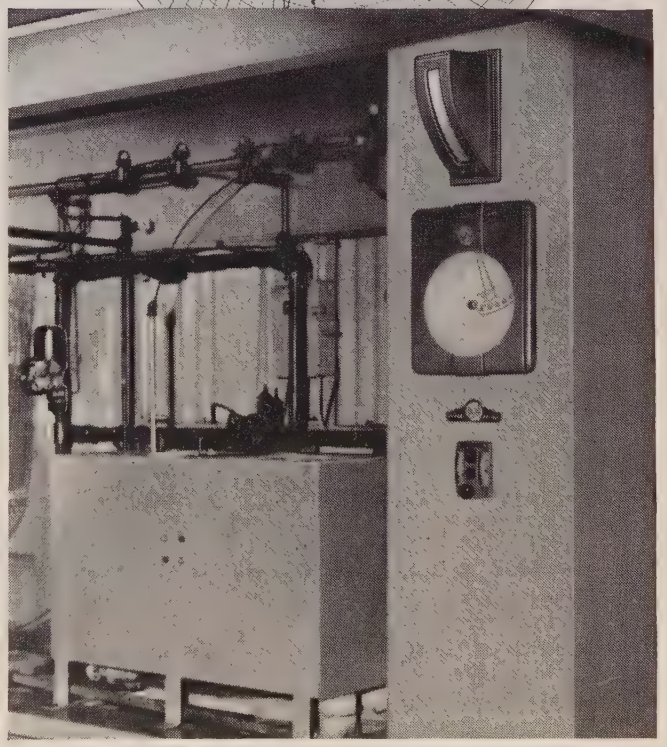

Bailey Continuous Freeness Recorder in operation at a Southern newsprint plant.

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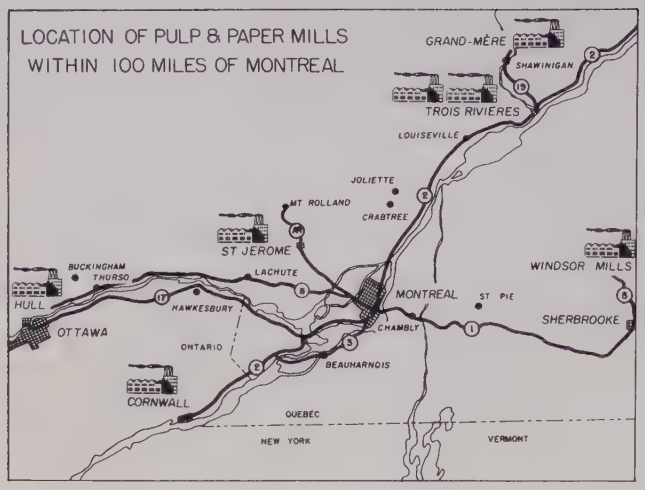

Both of these mills are on routes to Montreal from much of the United States. Watch for final details for these mill visits in the next release.

On the day immediately following the conference, a mill visit has been arranged to Rolland Paper Co. Ltd. at St. Jerome, Que. Also on this Friday, August 18, conferees may want to continue their visit to the Province of Quebec and to visit one or more mills in the Three Rivers area. Arrangements can be made at the conference to visit the following mills:

St. Lawrence Corp., Ltd., Three Rivers, Que.
Canadian International Paper Co., Three Rivers, Que.
Consolidated Paper Corp., Ltd., at both Three Rivers and Grand 'Mere, Que.

The feature visit of the conference will be to the new laboratories of the Pulp and Paper Research Institute of Canada at Pointe Claire, a suburb of Montreal. These laboratories were completed in 1958 and are a source of much of the excellent research in pulp and paper in Canada.

Committees of the Testing Division will be holding meetings, many jointly with the corresponding committee of the Technical Section of CPPA.

General chairman of the Conference is W. O. Kroeschell, technical director of the Michigan Carton Co., Battle Creek, Mich.

Eleventh TAPPI Corrugated Containers Conference

The Eleventh TAPPI Corrugated Containers Conference will be held at San Francisco, Calif., St. Francis Hotel, Sept. 6–8, 1961.

H. W. Wilson, Royal Container Co., San Francisco, Calif., and O. P. Wanamaker, Fibreboard Paper Products Corp., Antioch, Calif., are general conference co-chairmen.

Technical Program Chairman O. P. Wanamaker, Fiberboard Paper Products Co., Antioch, Calif., heads the technical programs being developed in cooperation with the TAPPI Corrugated Containers Division Production and Engineering Committees. L. F. Ashwood, Downing Box Co., Milwaukee, Wis., and A. Richardson, Crown Zellerbach Corp., St. Louis, Mo., are chairmen of these committees, respectively.

The first day of the technical program, Wednesday, September 6, is to be on "Adaption of Flexographic Printing to Corrugated" moderated by R. W. Catzen, Baltimore Paper Co., Baltimore, Md. It is intended to cover the development of flexographic printing, current equipment being manufactured for corrugated, and the present experience of corrugated converters in producing and merchandising flexographic printing on corrugated.

The Thursday, September 7, morning session is on "Use of Corrugated Containers in the Agricultural Field on the West Coast." G. Caploe, Longview Fiber Co., Oakland, Calif., is moderator. The papers are planned to develop the point that though these products might be currently limited to certain geographical areas, some of the designs, manufacturing equipment, and techniques might be employed in other areas for the same or other products.

"Engineering Developments" is the subject of the afternoon session to the moderated by A. Richardson, Crown Zellerbach Corp., St. Louis, Mo. This will cover the latest ideas on equipment and techniques.

Tours to plants of the Longview Fibre Co. in Oakland and Royal Container Co. in Millbrae are arranged for Friday, September 8.

All interested parties, members of TAPPI and nonmembers alike, are cordially invited to attend this Conference.

It is suggested that room reservations be made as soon as possible directly with the St. Francis Hotel.

Fundamental Research Symposium

A second international meeting is being organized by the Technical Section on the lines of the first symposium held in Cambridge in 1957, which dealt with "Fundamental Aspects of Fibers and Their Treatment for Papermaking"—see the book "Fundamentals of Papermaking Fibers."

This second symposium has as title: "The Formation and Structure of Paper."

The following summary gives the essential details of the symposium arrangements:

Dates—Registration on Sunday, Sept. 24, 1961. Sessions on Monday, Sept. 25 at 9:20 a.m. to Friday, Sept. 29, 1961 at 5:00 p.m.

Location—Sessions in the Organic Chemistry Lecture Theatre, Dyson Perrins Laboratory, South Parks Road, Oxford.

Accommodation—Christ Church or Randolph Hotel.

Social Events—A full program of social functions and an excursion has been arranged, as well as a program for ladies accompanying symposium registrants.

Fees—Registration for the symposium £12 per head. Social registration for registrants or accompanying ladies, £7. Alternatively, individual events can be attended and tickets for these will be available.

Program—The program will cover the following three main subjects and the treatment will range from the consideration of the fundamental factors to the application of these factors in the practical papermaking process—the structure of paper, the effect of structure on the major properties of paper, and the factors responsible in practice for the structure of paper.

Speakers and Chairmen of Sessions—Dr. J. A. Van den Akker, Dr. W. Brecht, Prof. J. d'A. Clark, Dr. H. Corte, Dr. H. E. Dadswell, H. W. Emerton, Dr. W. Gallay, Prof. H. W. Giertz, W. A. Gilmour, Dr. J. Grant, H. W. Hale, Dr. V. G. W. Harrison, Dr. H. G. Higgins, L. F. Hopkins, G. Hunger, Prof. G. Jayme, Dr. O. Kallmes, Dr. C. J. J. Ninck Blok, Prof. A. H. Nissan, D. H. Page, P. H. Prior, Dr. B. G. Rånby, Dr. H. F. Rance, A. E. Ranger, Prof. B. Steenberg, P. A. Tydeman, A. J. Watson, and Dr. R. P. Whitney.

Attendance at Symposium—The maximum seating capacity in the lecture theatre is 205 for registrants, exclusive of speakers and chairmen. Applications to attend will be dealt with therefore as received.

Fourth International Mechanical Pulping Conference

The Mechanical Pulping Committees of the Technical Association of the Pulp and Paper Industry and the Technical Section of the Canadian Pulp and Paper Association are working together in the preparation of a program for the

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Fourth International Mechanical Pulping Conference, which will be held at the Edgewater Beach Hotel in Chicago on Sept. 19–21, 1961.

World-wide participation is indicated by some of the speakers expected at this conference from Canada, England, Italy, Sweden, Germany, and the United States.

The high lights of the meeting will revolve around papers on Fundamentals of Grinding, Chip Groundwood, Bleaching and New Techniques for Increasing Capacity, and Improving Quality with Existing Grinder Equipment.

W. H. de Montmorency, Pulp & Paper Research Institute of Canada

A comprehensive review of new refining developments and current practices will take place, with particular emphasis on large-scale newsprint production. A complete session will be devoted to "The Layout of an Ideal Groundwood Mill," in which all attending will have the opportunity to participate.

W. H. de Montmorency, Pulp and Paper Research Institute of Canada, Montreal, Que., is general chairman of the conference. S. R. Parsons, Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., is technical program chairman. Local arrangements are being handled by A. A. Yankowski, Kimberly-Clark Corp., Neenah, Wis., and publicity is being handled by W. H. Copeland, Norton Co. of Canada, Hamilton, Ont.

T. F. La Haise, Ryegate Paper Co., East Ryegate, Vt., is chairman of the TAPPI Mechanical Pulping Committee and H. P. Richards, Ontario Paper Co., is chairman of the Technical Section, CPPA Mechanical Pulping Committee.

TENTATIVE PROGRAM

MONDAY, SEPT. 18, 1961

11:00 a.m. Mechanical Pulping Committees—Parkview Room TAPPI and Tech. Section CPPA
3:00–8:00 p.m. Registration—Passaggio

TUESDAY, SEPT. 19, 1961

7:30 a.m. Authors Breakfast—Parkview Room
8:00 a.m.–4:00 p.m. Registration—Passaggio
9:30 a.m. Session I—East Lounge

Opening Remarks: W. H. de Montmorency, Pulp and Paper Research Institute of Canada, Montreal, Que., conference chairman

Keynote Address: Lowell Besley, Pulp and Paper Research Institute of Canada, Montreal, Que.

10:15 a.m. Coffee Break

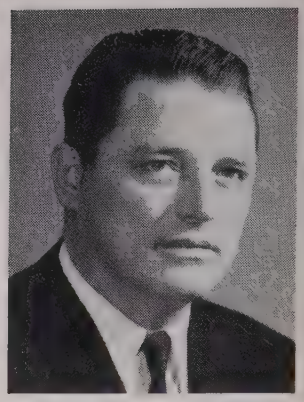
10:30 a.m.

1. "Mechanical Pulping Studies with a Model Steel Wheel," by D. Atack, Pulp & Paper Research Institute of Canada, Montreal, Que.
2. "Beat Production and Dissipation in the Grinding Zone of the Wood Grinder," by B. Steenberg and A. Nordstrand, Swedish Forest Products Research Laboratory, Paper Technology Department, Stockholm, Sweden.

2:00 p.m. Session II—East Lounge

3. "Energy Consumption in Mechanical Pulping," by G. E. R. Lamb, State University of New York, College of Forestry, Syracuse, N. Y.

S. R. Parsons, Consolidated Water Power & Paper Co.



A. A. Yankowski, Irving Pulp & Paper Co., Ltd.

3:00 p.m.

4. "Laboratory Investigation on Relations between Conventional Characteristics and Printability," by Otto Brauns and O. Swanberg, Pappersbrukens Centrallaboratorium, Stockholm, Sweden.
5. "Comparison of Intermittent and Continuous Grinders," by W. Brecht, Institute fur Papierfabrikation, Der Technischen Hochschule Darmstadt, Darmstadt, West Germany and F. Luhde, Anglo Paper Products, Ltd., Quebec, Que.

WEDNESDAY, SEPT. 20, 1961

7:30 a.m. Authors Breakfast—Parkview Room
8:00 a.m.–4:00 p.m. Registration—Passaggio
9:00 a.m. Session III—East Lounge

6. "The Development and Production of Disk Refiner Groundwood Pulp," by W. F. Holzer, J. T. Henderson, W. B. West, and K. F. Byington, Crown Zellerbach Corp., San Francisco, Calif.

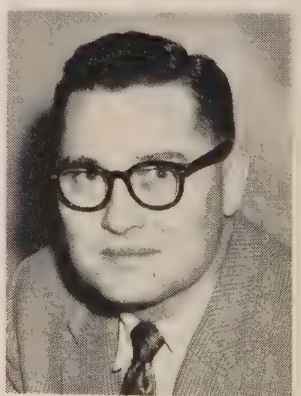
10:30 a.m. Coffee Break
10:45 a.m.

7. "Mechanical Pulp by Refining of Hardwood and Softwood Chips," by R. M. Dorland, Abitibi Power and Paper Co., Ltd., Sault St. Marie, Ont.

2:00 p.m. Session IV—East Lounge

8. "Cold Caustic Pulp from Single-Stage Refining," by V. B. Bodenheimer, Continental Can Co., Augusta, Ga.
9. Panel Discussion: "Mechanical Pulp from Chips." Panel Members: J. H. Fisher, MacMillan & Bloedel and Powell River, Ltd., Nanaimo, B.C., Canada;

W. H. Copeland, Norton Co. of Canada



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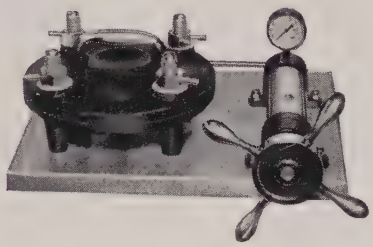

Mounted on 18-8 Stainless steel base. Press on base, or pump only may be purchased separately. (T-205 m)

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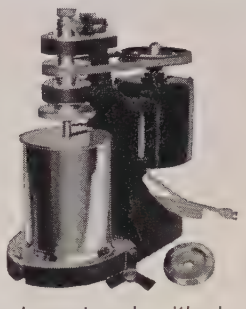

Standard equipped with bronze chromium plated container bowl and stainless steel chuck, collet and shaft assembly. (T-205 m)

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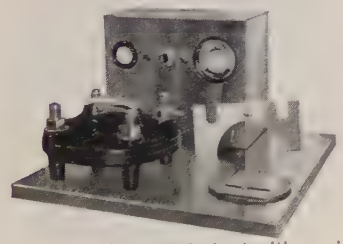

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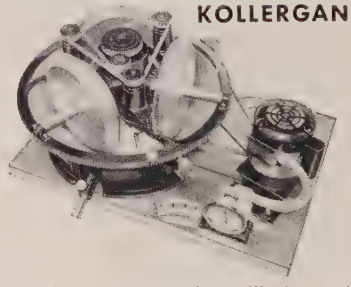

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J. E. Foote, Diamond National Corp., Stamford, Conn.; K. C. Logan, Anglo Paper Products Ltd., Quebec, Que., Canada; J. N. Swartz, Bowaters Southern Paper Corp., Calhoun, Tenn.; P. E. Trout, Waldorf Paper Prod., St. Paul, Minn.

3:30 p.m. Break
3:45 p.m. Panel Discussion, continued
6:00 p.m. Suppliers' Reception—East Lounge
7:30 p.m. Banquet—Ballroom

Toastmaster: W. H. de Montmorency, Pulp and Paper Research Institute of Canada, Montreal, Que., Canada, conference chairman

9:30 p.m. Dance—East Lounge

THURSDAY, SEPT. 21, 1961

7:30 a.m. Authors Breakfast—Parkview Room
8:00 a.m.–2:00 p.m. Registration—Passaggio
9:00 a.m. Session V—East Lounge

10. "Bersano Grinding Process," by Piero Bersano, Cartiere Burgo, Torino, Italy.

10:30 a.m. Coffee Break
10:45 a.m.

11. Panel Discussion: "Grinder Operation Breakthrough." Panel Members: C. Anker, Risor Tremassefabriker, Risor, Norway; J. W. Griffin, Great Northern Paper Co., Millinocket, Me.; R. Murley, Bowaters Newfoundland Pulp and Paper Co., Ltd., Cornerbrook, Nfld.; H. P. Richards, The Ontario Paper Co., Ltd., Thorold, Ont., Canada; G. W. Thompson, Bowaters Research and Development Co., Ltd., London, England; H. J. Turmaine, Abitibi Power and Paper Co., Ltd., Port Arthur, Ont., Canada.

2:00 p.m. Session VI—East Lounge

12. "Relations of Groundwood Screening Procedures," by W. Brecht, Institut fur Papierfabrikation, Der Technischen Hochschule Darmstadt, Darmstadt, West Germany, and A. Weidhaas.
13. "High Density Groundwood Bleaching," by D. M. Ferguson, St. Regis Paper Co., Deferiet, N. Y.

3:15 p.m. Break
3:30 p.m.

14. Panel Discussion: "Layout of an Ideal Groundwood Mill." Panel Members: Representatives from newsprint, book, tissue, board and custom groundwood mills.

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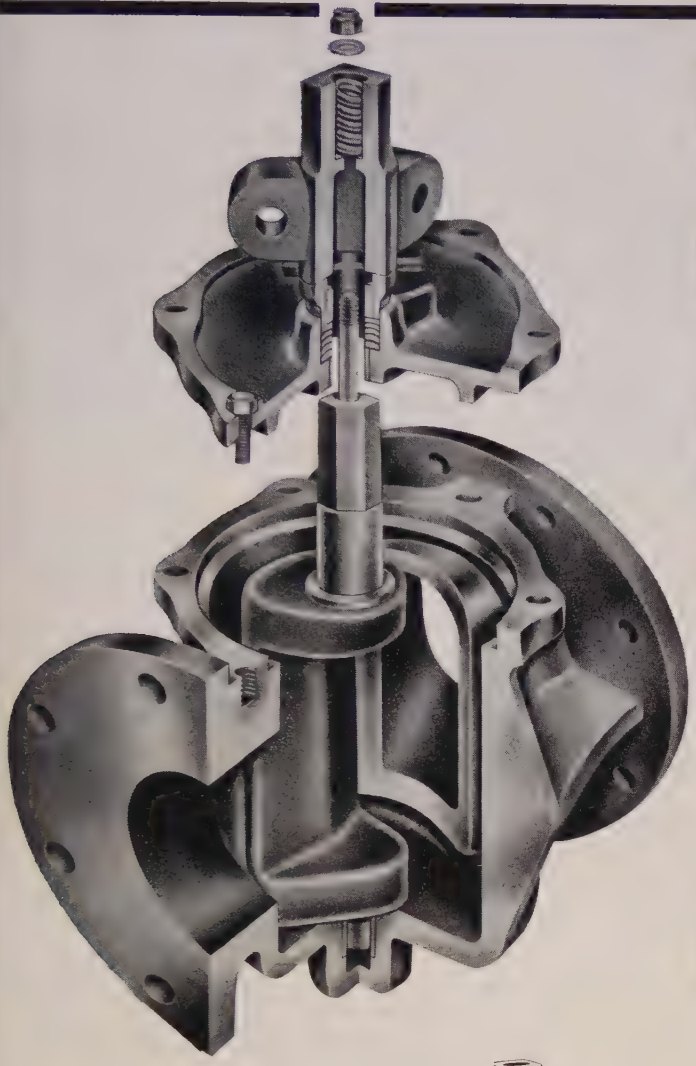

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TAPPI NOTES

TAPPI Technical Information Sheets

TAPPI Technical Information Sheets, a new series of TAPPI publications, will soon make their appearance, both in the *Tappi* journal and in loose-leaf form. The new sheets are the successors to the familiar TAPPI Data Sheets which have been published over the past 15 years.

The decision to embark upon a new program for the dissemination of technical information was based on a desire to overcome several rather difficult problems which had plagued the Data Sheets program for many years. Lack of sustained supervision of the program, little coordination of effort, and inadequate means for verification of results had led to the publication of material of less than satisfactory quality. An adequate system of classification had not been developed. The project had been confined to the Engineering Division of TAPPI, and thus was not realizing its full potential scope of embracing the activities of all 63 technical committees of the Association.

Sustained supervision, coordination, and verification could be achieved, it was felt, only through the appointment of a supervisor who could give to all phases of the program the continuous attention to detail needed to achieve high quality through adequate verification procedures, and to maintain such quality through the initiation of periodic review and re-examination of published material. During the summer of 1960, a subcommittee of the Engineering Division's Staff Advisory Committee studied this problem and drafted a recommendation for presentation to the Technical Operations Committee and subsequently to the TAPPI Executive Committee. Members of the subcommittee were W. C. Bloomquist, N. Shoumatoff, G. E. Shaad, and M. J. Osborne.

The recommendation, after approval by the Technical Operations Committee, was approved in principle by the Executive Committee on Sept. 27, 1960. It provided for the employment of a full-time Supervisor of Technical Information and for funds to set up an adequate verification procedure. It envisioned a broadening of the scope of the former Data Sheets program to include all technical activities of the Association. The new Technical Information Sheets will thus include useful technical information of interest to all scientists and engineers engaged in the manufacture or conversion of pulp, paper, and allied products. The recommendation also provided for overall supervision of the Technical Information Program by the Technical Operations Committee. This committee is composed of the general chairmen of the eight technical divisions of TAPPI, with the Technical Secretary as chairman, and is thus the logical supervisory body for a program that embraces the activities of all the technical committees.

Following Executive Committee approval, the Technical Operations Committee prepared for the implementation of the plan by drafting proposed regulations for Technical Information Sheets and recommended procedures for the operation of the program. This work was done by Messrs. Shaad, Shoumatoff, Bloomquist, and Osborne, now acting as a subcommittee of the Technical Operations Committee. The proposed regulations and operating procedure were approved by the Technical Operations Committee on Nov. 21, 1960, and adopted by the Executive Committee on Feb. 19, 1961.

Meanwhile, the headquarters staff, with the help of the above subcommittee, was searching for a qualified man to fill the post of Supervisor of Technical Information. On April 3, 1961, Albert S. Landers was employed in this capacity. Mr. Landers has had broad experience in the pulp, paper, and allied industries since graduating from the Forestry Department of the University of Maine in 1937. He has been associated with Scott Paper Co., St. Regis Paper Co., Day & Zimmermann, Inc., Eastwood-Nealley Corp., and the Philadelphia Quartz Co. in capacities which have ranged from research through marketing.

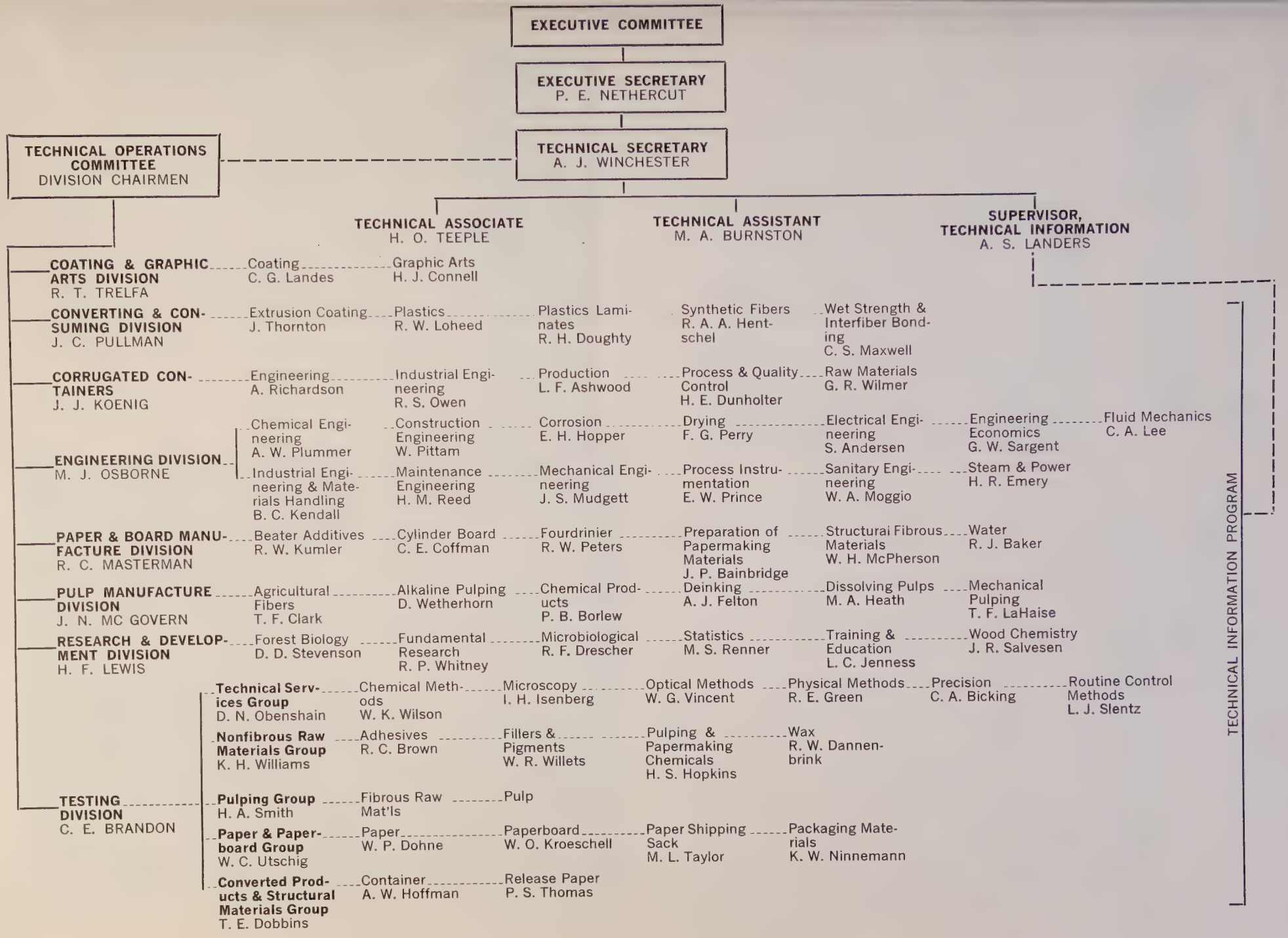
The development of an adequate system for classifying pulp and paper technical information will be one of the first major requirements of the new program. Such a system of indexing or classifying will be of great value from two points of view. Firstly, it will focus attention upon those areas of pulp and paper technology where technical information is lacking, and will thus help to indicate the most fruitful sources for the development of TAPPI Technical Information Sheets. In so doing, it may give direction to the activities of many TAPPI technical committees. A second and more obvious value of a good classification system will be its ability to facilitate retrieval of published information and thus make the Technical Information Sheets more readily usable by the industry's scientists and engineers.

Grateful acknowledgment is hereby made of the vast amount of time and effort given by the many TAPPI members who have worked with the Data Sheets program in the past, and in particular to the following past chairmen of the Data Sheets Committee:

H. J. Perry	1950–1952
J. W. Hemphill	1953–1956
F. Helversen	1956–1957
H. G. Ingraham	1958–1961

The breadth of scope envisioned for the new program is indicated by the following definition of TAPPI Technical Information Sheets.

"The technical information, data, and recommended practices applicable in the manufacturing and converting of pulp, paper, and paper products will include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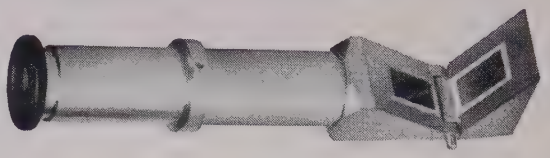

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material not logically available to industry technologists. Such technical information may include data supplied by manufacturers as well as applicable textbook and handbook references.

The information presented may fall into any one of three classifications:

1. Proved data that have been developed from established mathematical and physical relationships. Such data frequently are presented in chart or nomograph form.

2. Established information developed by analysis of operating procedures.

3. General information developed by paper companies, equipment manufacturers, committees, or individuals."

All members of TAPPI are urged to support and encourage the new program in any way they may choose. Suggestions concerning the kind of technical information most urgently needed will be welcomed by TAPPI headquarters. Data, recommended practices, or any other technical information useful in the pulp and paper field should be submitted to headquarters for consideration. It will only be through the continuing contributions of the members themselves that the new program will become an extremely useful and important service to all TAPPI members.

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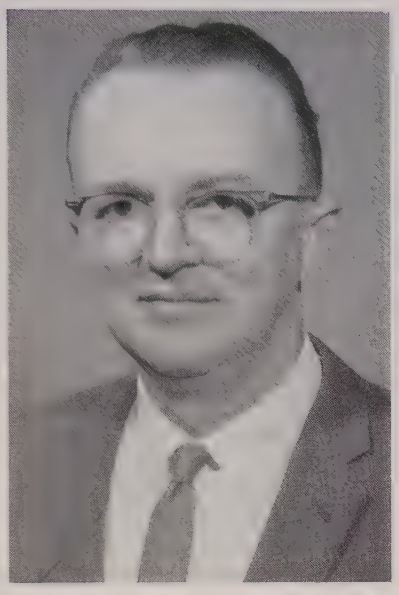

Glenn C. Kimble

GLENN C. KIMBLE, a member of the Executive Committee, is plant technical director of Union Bag-Camp Paper Corp. in Savannah, Ga.

Born in 1915 in Norfolk, Neb., he obtained his primary education there, and was high school valedictorian. In 1937 he graduated B.S. in chemical engineering from Iowa State College. He became interested in paper as a career while working the Agricultural By-products Laboratory at Iowa State, investigating papermaking fibers. Winning a scholarship to The Institute of Paper Chemistry, his Ph.D. thesis research was on the colored materials of alkaline cooking liquors. His work, for which he received a Ph.D. from Lawrence College in 1941, is one of the early attempts to establish the relationship between the color of kraft and soda black liquors and the chemical composition of the liquors [*Paper Trade J.* 115, No. 3: 37–46 (July 16, 1942)].

Before graduating he spent his summers working for Nekoosa-Edwards, Port Edwards, Wis.; Detroit Sulphite, Detroit, Mich.; and the Northwest Paper Co., Cloquet, Minn. Upon graduating from Lawrence College, he joined Gardner Board and Carton (now Diamond National) in Cincinnati, Ohio, as a research chemist, working on mill problems. In 1944 he went to Minnestota and Ontario Co., in International Falls, Minn., as supervisor of insulation board research.

In 1948 he joined Union Bag-Camp Corp. in Savannah, Ga., as superintendent of the mill technical department. Since 1956 he has been plant technical director. In that year he published an article on the maintenance and standardization of paper testing instruments [*Tappi* 39, No. 2:171A–181A (Feb., 1956)], which has proved invaluable in teaching customers how to test papers correctly. More than 4000 reprints of the article have been distributed to date.

He takes a keen interest in the development of young engineers fresh out of college. Aware that frequently we do not know what we have found until we come to write about it, he is especially interested in helping them to plan their technical work and to write effectively about it.

Glenn Kimble has been a member of TAPPI since 1940. During the past 15 years he has been a member of the structural fibrous materials (1947), pulp testing (1953), wet strength (1954), and semichemical pulping (1954) committees. While he was chairman of the subcommittee on structural fibrous materials the development of test methods for insulation board was undertaken, and as a result of a cooperative effort with the Forest Products Laboratory, information was developed which later led to the SFMC drainage tester and TAPPI Standard T 1002 sm-51.

At present he is a member of the sulfite pulping, the sanitary engineering and publications committees. He is also a member of the APPA research coordination committee, and was program chairman for the joint APPA-TAPPI Research Conference in Chicago, in 1959.

Perhaps one of his most outstanding contributions to TAPPI is the leadership he provided during the founding of the Southeastern Section. He was chairman of both the organizing committee for this section and the Southeastern Pulp and Paper Society, which was granted a charter as the Southeast Section of TAPPI one year after it was established. He then continued as the Southeast Section chairman for one more year. So successful was he in formulating plans and schedules for meetings and in enlisting the cooperation of management that R. G. Macdonald, then secretary-treasurer of TAPPI, referred to him all inquiries on how to start a TAPPI section. He also gave valuable help to the Gulf Coast Section during its formative period.

Glenn Kimble performs various services for his community. He has organized an extracurricular science seminar for outstanding high school science students in Savannah, and was chairman of the group giving this seminar which offers almost a year of weekly $2^1/_2$-hour programs covering biology, physics, chemistry, mathematics, engineering, and medicine. He is a judge at high school science fairs and is constantly working to foster an interest in science in high schools.

He is a member of the Technical Committee of the Southern Region for the National Council for Stream Improvement, chairman of the Georgia Pulp and Paper Association Water Resources Committee, member of the Savannah Chamber of Commerce and of its Water Pollution Committee, the Georgia Water Quality Council (the state pollution control board), and of the Georgia Water Resources Commission (a water-use planning body), and of the Kiwanis Club.

He lives in Savannah where he belongs to the First Presbyterian Church. His wife is the former Caroline Story of Butte, Neb. They have two children, Christie, 17, and Vicky 16. He is fond of gardening, landscaping, and bridge.

PERSONAL MENTION

New TAPPI Members

Allardice, Thomas B., Vice-President and Consultant, Sumco Engineering, Inc., Caldwell, N. J.

Allen, Arthur C., Jr., Plant Manager, Eastern Box Co., Baltimore, Md., a 1943 graduate of Georgia Institute of Technology.

Amneus, John S., Engineer, Procter & Gamble Co., Cincinnati, Ohio, a 1939 graduate of University of California.

Anglesio, Giorgio, Production Manager, Manifattura Ceramica Pozzi, Milan, Italy.

Areson, William H., President and Treasurer, Noble & Wood Machine Co., Hoosick Falls, N. Y., a 1936 graduate of New York University.

Asplund, C. Gosta, Deputy Managing Director, Defibrator A.B., Stockholm, Sweden, a 1926 graduate of Harvard Business School.

Austin, Rupert H., Jr., Felt Sales Engineer, Huyck Felt Co., Rensselaer, N.Y., a 1948 graduate of Brown University with a Ph.D. degree in 1959 from St. Andrew's College.

Baker, Thomas N., Engineer in charge of Chip Supply, St. Regis Paper Co., Jacksonville, Fla., a 1950 graduate of University of Florida.

Baldwin, Gary D., Chemist, Shawano Paper Mills, Shawano, Wis., a 1960 graduate of Luther College.

Barbaro, Amelio, Chief Electrical Engineer, Robert Gair Paper Products Group, Continental Can Co., New York, N. Y., a 1936 graduate of Rennsselaer Polytechnic Institute.

Barnett, James M., Technical Liaison Supervisor, Ducilo S.A.I.C., Roca, Argentina, a 1937 graduate of University of Buenos Aires with a Ph.D. degree.

Baumrucker, William, Jr., Engineer, Chas. T. Main, Inc., Boston, Mass., a 1929 graduate of Massachusetts Institute of Technology.

Beardwood, Bruce A., Technical Representative, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., a 1958 graduate of Yale University.

Beeman, Robert H., Chemist, E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., a 1942 graduate of Ohio Wesleyan University.

Bernard, James H., Sales Engineer, Babcock & Wilcox, Boston, Mass., a 1951 graduate of University of Michigan.

Boddorff, Robert E., District Manager, Hercules Powder Co., Houston, Tex., a 1945 graduate of Worcester Polytechnic Institute.

Borgeson, Anders E., Research and Development Assistant, National Lead Co., Brooklyn, N. Y., a 1959 graduate of University of Maine.

Bradley, John J., Sales Engineer, Link-Belt Co., Needham Heights, Mass., a 1945 graduate of Villanova University.

Braillon, M., Engineer, Compagnie des Atchin et Forges de la Loiri, St. Chamond, France.

Brenneman, Richard S., Chemist, Arthur D. Little, Inc., Cambridge, Mass., a 1951 graduate of Boston University.

Brewster, Ernest B., President and Owner, Labelon Corp., Rochester Ribbon & Carbon Co., Inc., Canandaigua, N. Y., a 1939 graduate of University of Colorado.

Bricker, Melvin I., Executive Vice-President, Interstate Container Corp., Glendale, L. I., a 1941 graduate of Villanova University.

Brown, Alan M., Chief Chemist, British Rayophane, Ltd., Cumberland, England, a 1954 graduate of Bradford Institute of Technology with a Ph.D. degree in 1959.

Brown, Harry W., Manager, Gilbert & Nash Div., Appleton Machine Co., Appleton, Wis.

Burr, Francis K., Chemist, Fabric Research Labs, Inc., Dedham, Mass., a 1933 graduate of Wesleyan University.

Canesi, Gianluigi, Consultant, Cartiere del Timavo S.p.A., Trieste, Italy, a 1954 graduate of Politecnico Di Milano with a Ph.D. degree.

Carpenter, Howard A., Sales Engineer, Manitowoc Shipbuilding, Inc., Manitowoc, Wis., a 1940 graduate of University of Colorado.

Carr, Hugh E., Product Manager, Hagan Chemicals & Controls, Inc., Pittsburgh, Pa., a graduate of Pennsylvania State University.

Carr, Wayne F., Director of Pulp Laboratory, Black-Clawson Co., Middletown, Ohio, a 1957 graduate of Western Michigan College.

Charters, Michael T., Technical Representative, Bauer Bros. Co., Springfield, Ohio, a 1955 graduate of Xavier University.

Chen, Chao Hon, General Manager, Shih Lin Paper Corp., Ltd., Taiwan, Formosa, a 1954 graduate of National Taiwan University.

Clark, Dorothy L., Librarian, U.S.I.S. Bombay, Dept. of State, Washington, D. C., a 1923 graduate of Stanford University.

Copeland, Garnet G., Assistant to Vice-President, Container Corp. of America, Carthage, Ind., a 1936 graduate of University of New Brunswick, Canada.

Cramer, H. Eugene, Technical Director, Diamond National Corp., Gardner Div., Middletown, Ohio.

Curtis, Frank W., President, Lexsuco, Inc., Solon, Ohio, a 1939 graduate of Yale University.

Cutts, Howard H., Technical Director, Union Paste Co., Hyde Park, Mass., a 1928 graduate of Northeastern University.

Dalfen, Manuel M., Project Engineer, Abitibi Power and Paper Co., Ltd., Georgetown, Ont., Canada, a 1959 graduate of University of Toronto.

Davis, Michael P., Coatings Salesman, Dow Chemical Co., Buffalo, N. Y., a 1960 graduate of Canisius College.

Deobald, John R., Sales Engineer, American Alloy Corp., Cleveland, Ohio, attended Purdue University.

Doherty, Philip B., Chief Inspector, The Mead Corp., Leominster, Mass., a 1957 graduate of Worcester Junior College.

Dunn, Robert E., Engineer, Bowaters Southern Paper Corp., Calhoun, Tenn., a 1952 graduate of Auburn University.

Ehrenberg, Harold J., Salesman, Sandoz, Inc., New York, N. Y., a 1952 graduate of St. Johns College.

Eklund, Rolf-Bertil, Head, Development Dept., AB Svenska Maskinverken, Kallhall, Sweden, a 1944 graduate of Royal Institute of Technology.

Elkins, William J., Engineer, Mount Hope Machine Co., Taunton, Mass., a 1925 graduate of Cornell University.

Fairest, Roger W., Pulp and Paper Research Technologist, Universidad de los Andes, Merida, Venezuela, a 1958 graduate of University of Manchester.

Fletcher, Howard R., Assistant Plant Manager, Link Paper Co., Englewood, N. J., attended Fairleigh Dickinson University.

Forgacs, Otto L., Project Supervisor, Pulp and Paper Research Institute of Canada, Montreal, P.Q., Canada, a

1955 graduate of University of Manchester with a Ph.D. degree in 1959 from McGill University.

Friedrich, Heinrich K., Manager, Eucatex S.A., Sao Paulo, Brazil, a 1930 graduate of Heidelberg University with a Ph.D. degree.

Galphin, Richard W., Assistant Pulp Mill Superintendent, Container Corp. of America, Fernandina Beach, Fla., a 1951 graduate of Georgia Institute of Technology.

Gilbert, Eugene C., Partner, Gilbert & Shields, Montreal, P. Q., Canada. Attended University of Maine and University of Pittsburgh.

Gray, Dean L., Assistant Technical Superintendent, Bowaters Carolina Corp., Catawba, S. C., a 1951 graduate of Purdue University.

Green, Richard H., Technical Director, Chillicothe Paper Co., Chillicothe, Ohio, a 1954 graduate of Rose Polytechnic Institute.

Greene, Udell T., Supervisor, Pulp & Paper Lab., Diamond Alkali Co., Painesville, Ohio, a 1929 graduate of Hiram College with a Ph.D. degree in 1933 from Rensselaer Polytechnic Institute.

Gregg, Walter E., Jr., Regional Manager, Eaton Mfg. Co., Caldwell, N. J., a 1939 graduate of Cornell University.

Gronendyke, Paul M., Technical Service Supervisor, National Starch and Chemical Corp., Chicago, Ill., a 1950 graduate of Purdue University.

Hall, Daniel H., Manager, Paper Chemicals Lab., Nopco Chemical Co., Newark, N. J., a 1947 graduate of Clarkson College.

Hardy, Paul E., Chemist, Enjay Chemical Co., Elizabeth, N. J., a 1941 graduate of Purdue University.

Harold, Vincent C., Jr., Sales Representative, The Flintkote Co., New York, N. Y.

Hayes, James S., Sales Engineer, The Black-Clawson Co., Inc., Watertown, N. Y., a 1950 graduate of Swarthmore College.

Herbst, J. H. E., Senior Research Chemist, Industrial Cellulose Research, Ltd., Hawkesbury, Canada, a 1944 graduate of University of Toronto with a Ph.D. degree in 1949.

Hewitt, William J., Jr., Paper Technician, Curtis Publishing Co., Philadelphia, Pa.,

Hillard, George O., Jr., Section Head, Esso Research Labs., Humble Oil & Refining Co., Baton Rouge, La., a 1937 graduate of Louisiana State University.

Hofreiter, Bernard T., Acting Head, Northern Utilization Research & Development Div., U.S.D.A., Peoria, Ill., a 1950 graduate of Bradley University.

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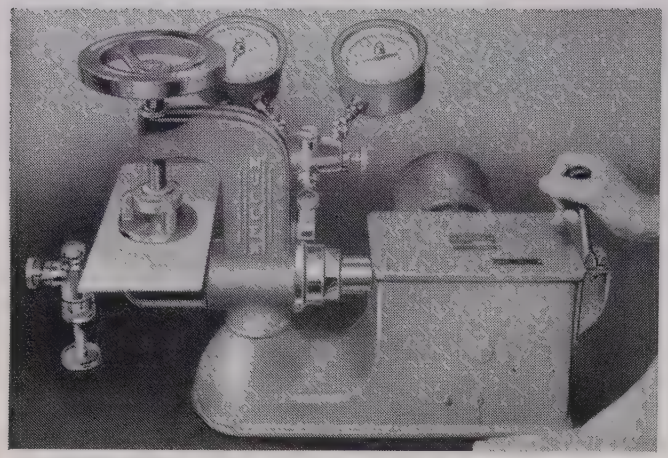

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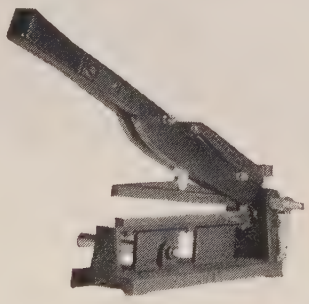

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Hoth, Frederick D., Technical Control Manager, Ben-Mont Div., Dow Chemical Co., Bennington, Vt., a 1942 graduate of University of Notre Dame.

Hough, Katharine M., Librarian, Crown Zellerbach Corp., Bogalusa, La.

Jensen, Ib Hunderup, Civil Engineer, Joint Purchase Association of the Danish Newspress, Copenhagen, Denmark, a 1942 graduate of Danish Technical High School.

Klop, Gerritt, Service Engineer, Cyanamid International Corp., Amsterdam, Holland. Attended Hogere Technische School, Amsterdam.

Knight, Donald G., Vice-President, Bulkley, Dunton Pulp Co., Inc., Kalamazoo, Mich., a 1941 graduate of Dartmouth College.

Knight, Robert M., Technical Director, Weyerhaeuser Co., Everett, Wash., a 1949 graduate of University of Washington.

Lawver, Earl A., Manager of Pulp Mill Engineering, Fibreboard Paper Products Corp., San Francisco, Calif., a 1947 graduate of University of California.

Levine, Ralph M., Group Leader, Marbon Chemical Div., Borg-Warner Corp., Washington, W. Va., a 1950 graduate of University of Glasgow.

Lindquist, Gustaf B., Assistant to President, Lewis Roberts, Inc., Newark, N. J., a 1943 graduate of Harvard University.

Loeser, Donald B., Vice-President, Paper Machinery Corp., Milwaukee, Wis., attended University of Wisconsin.

Long, Robert P., Editorial Director, Graphic Magazines, Inc., Garden City, N. Y., a 1935 graduate of Parsons College.

Macaluso, Pat, Head, Research Dept., Stauffer Chemical Co., Chauncey, N. Y., a 1946 graduate of Polytechnic Institute of Brooklyn.

Maloney, James D., Jr., Associate Director of Research, the Mead Corp., Chillicothe, Ohio, a 1943 graduate of University of Tennessee.

Marrazza, Giulio, Technical Director, CEPRAT, Ceprano, Frosinone, Italy, a graduate of Universita di Napoli with a D. Eng. degree.

Marzocchi, Alfred, Manager, Industrial Development Laboratory, Owens-Corning Fiberglass Corp., Ashton, R. I., a 1949 graduate of Syracuse University.

Masloski, S. H., Librarian, Heyden-Newport Chemical Corp., Garfield, N. J.

Mason, George A., Technical Librarian, St. Regis Paper Co., Carthage, N. Y., a 1959 graduate of Western Reserve University.

Mason, James A., Director of Application Engineering, Mixing Equipment Co., Inc., Rochester, N. Y., a 1950 graduate of Illinois Institute of Technology.

McCormick, D. F. M., Manager, Technical Services, Industrial Raw Material Corp., New York, N. Y., a 1933 graduate of Columbia University.

Medlen, Lester R., Project Engineer, Continental Can Co., Inc., Chicago, Ill., a 1951 graduate of Indiana Technical College.

Meerbaum, Sam, Section Head, Mechanical Development, M. W. Kellogg Co., Jersey City, N. J., Attended Massachusetts Institute of Technology.

Menard, Robert J., District Representative, Nalco Chemical Co., Chicago, Ill., a 1953 graduate of Worcester Polytechnic Institute.

Mills, Harold W., Inspector Technician, Champion Paper and Fibre Co., Canton, N. C., a 1958 graduate of North Carolina State College.

Mol, Gerhard, President, Luneburger Wachsbleiche G. m. b. H., Luneburger, Germany.

Moore, Sewell T., Research Chemist, R. T. Vanderbilt Co., East Norwalk, Conn., a 1942 graduate of University of North Carolina.

Morgan, Henry M., Assistant Director, Fabric Research Laboratories, Inc., Dedham, Mass., a 1948 graduate of Massachusetts Institute of Technology with a Sc.D. degree in 1960.

Morgan, Ronald C., Technical Assistant to the Superintendent, Michigan Carton Co., Battle Creek, Mich., a 1956 graduate of Western Michigan University.

Morris, Kent B., Application Engineer, Robert E. Mason & Co., Charlotte, N. C., a 1952 graduate of Georgia Institute of Technology.

Mustacchi, Henry, Sales Manager and President, Tradeway International Corp., New York, N. Y., a 1939 graduate of University of Paris.

Mustonen, Erkki O., Design Engineer, Sandwell and Co., Ltd., Vancouver, B. C., Canada, a 1952 graduate of Finland Institute of Technology.

Ness, John R., Research Chemist, E. I. du Pont de Nemours & Co., Inc., Penn's Grove, N. J., a 1952 graduate of University of Denver.

Neumann, Hubertus, Manager, Buchmann, G.m.b.H., Rinnthal/Sarnstall, Germany, a 1951 graduate of Technische Hochschule, Darmstadt.

Oliveira, Jose Manuel S., Technical Director, Companhia de Celulose do Ultramar Portugues, Angola, Portuguese W.A.

Peckham, John R., Research Aide, The Institute of Paper Chemistry, Appleton, Wis.

Petcoff, Pete, Area Engineer, Bowaters Southern Paper Corp., Calhoun, Tenn., a 1953 graduate of University of Toronto.

Petrich, William, Chemist-Technical Sales, Enterprise Paint Mfg. Co., Chicago, Ill.

Pinney, George C., Development Chemist, A. E. Staley Manufacturing Co., Decatur, Ill., a 1939 graduate of University of Illinois.

Pomerantz, Philip M., Lubrication Engineer, Mobil Oil Co., New York, N. Y., a 1950 graduate of New York University.

Quackenbush, Harold R., Assistant Chief Chemist, St. Joe Paper Co., Port St. Joe, Fla., a 1954 graduate of New York University.

Ralston, Glenn, Salesman, Hank D. Jones & Associates, St. Petersburg Beach, Fla.

Ramsdell, Earl W., Chemical Engi-

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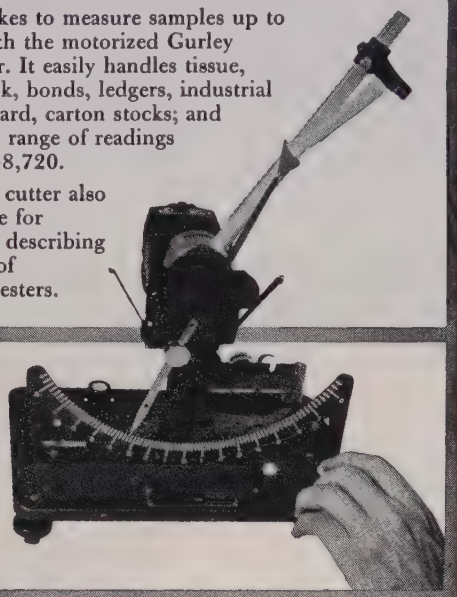

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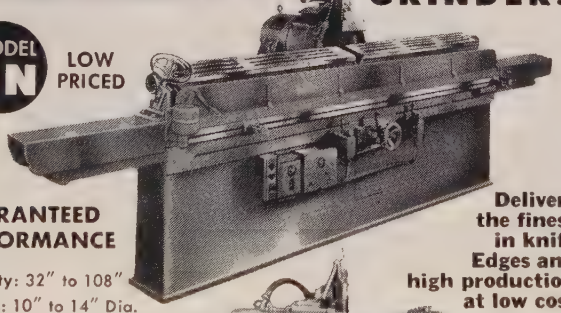

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neer, S. D. Warren Co., Cumberland Mills, Me., a 1959 graduate of University of Maine.

Rhyne, Wade H., Sales Branch Manager, Foxboro Co., Birmingham, Ala., a 1947 graduate of Georgia Institute of Technology.

Riihimaki, Erkki O., Technical Director, Societa Cartierl Tiburtine, Rome, Italy.

Royston, Charles H., Production Manager, Owens-Illinois Paper Products Div., Atlanta, Ga., attended Findley Engineering College.

Sama, Dominick A., Associate Professor, Lowell Technological Institute, Lowell, Mass., a 1954 graduate of Massachusetts Institute of Technology with a Sc.D. degree in 1960.

Schelling, Peter C., Vice-President, E. H. Schelling & Co., Zurich, Switzerland, a 1955 graduate of Juventus College, Zurich.

Schlumberger, Alan A., Technical Service Representative, Hooker Chemical Corp., Tacoma, Wash., a 1955 graduate of Stanford University.

Serafin, John F., Technical Service Representative, Electric Reduction Co. of Canadá, Ltd., No. Vancouver, B. C., Canada, a 1950 graduate of University of Manitoba.

Shapiro, Marvin, General Manager, Kleen-Stik Products, Inc., Newark, N. J., a 1943 graduate of City College of New York.

Shepherd, Henry H., Vice-President, Bird Machine Co., So. Walpole, Mass., a 1930 graduate of Northeastern University.

Spitz, Rodney D., Chemist, The Dow Chemical Co., Midland, Mich., attended University of Michigan.

Stahre, Goran, Mill Manager, Svenska Cellulosa AB, Svartvik, Sweden., attended The Royal University of Technology, Stockholm.

Stanley, Edward L., Manager, Tokyo Branch, Far East Chemical Services, Inc., Tokyo, Japan, a 1940 graduate of Princeton University with a Ph.D. degree in 1947.

Suarez G., J., Plant Manager, Celanese Mexicana, S.A., Rio Bravo, Tamps., Mexico, a 1948 graduate of Universidad Nacional de Mexico.

Sullivan, William F., National Accounts Representative, Dx Sunray Oil Co., Tulsa, Okla., a 1930 graduate of Providence College.

Tarr, Richard C., Technical Service, S. D. Warren Co., Muskegon, Mich., a 1951 graduate of New York State College of Forestry.

Tellez, Alfonso, Plant Chemist, Carton De Columbia S.A., Cali, Colombia, a 1947 graduate of University of Illinois.

Trainor, John W., Marketing, Babcock & Wilcox Co., Barberton, Ohio, a 1953 graduate of U. S. Merchant Marine Academy.

Turner, Elizabeth, Librarian, Northern Utilization Research and Development Div., Peoria, Ill.

Van Keuren, Lewis K., Quality Control Supervisor, Tri-Wall Containers, Inc., New York, N. Y., a 1958 graduate of Union College.

Vickery, Charles H., Vice-President, E. D. Jones Corp., Pittsfield, Mass., attended Clarkson College.

Villalobos, Jose A., Mechanical Engineer, J. O. Ross Engineering Div., Midland-Ross, New York, N. Y., a 1958 graduate of Wisconsin State College.

Von Engelhardt, Ivar, Trainee Executive, Ngoye Paper Mills (Pty), Ltd., Zululand, South Africa, a 1960 graduate of Technical University, Darmstadt.

Von Wietersheim, Eugen, Research Chemist, W. R. Grace & Co., Overseas Chemical Div., Cambridge, Mass., a 1958 graduate of Federal Institute of Technology, Switzerland, with a Ph.D. degree.

Walsh, Edward J., Customer Service, Dow Chemical Co., Midland, Mich., a 1952 graduate of North Dakota State University.

Wanamaker, Orville P., Manager, Container Research, Fibreboard Paper Products Corp., Antioch, Calif., a 1941 graduate of San Jose State College.

Watanabe, Sadayoshi, Professor, Dept. of Applied Chemistry, Hokkaido University, Sapporo, Japan, a 1935 graduate of Tokyo University.

Weatherly, J. R., Jr., Project Engineer, Bowaters Engineering & Development, Inc., Calhoun, Tenn.

Weiss, Stanton M., General Manager and Vice-President, Protective Coatings Corp., Clifton, N. J., a 1949 graduate of Rutgers University.

Welton, Ralph C., Assistant Technical Director, Alaska Lumber & Pulp Co., Inc., Sitka, Alaska, a 1937 graduate of Colorado State University.

Wickwire, Lawrence D., Chief Engineer, Paper Div., Price Brothers & Co., Ltd., Kenogami, P.Q., Canada.

Wirtanen, Andy O., Production Superintendent, The Celotex Corp., L'Anse, Mich., a 1949 graduate of Queen's University.

Wiberg, William A., Project Engineer, Research & Development Div., Consolidated Water Power and Paper Co., Wisconsin Rapids, Wis., a 1953 graduate of University of Wisconsin.

Wise, Robert L., Coatings Customer Service Chemist, Dow Chemical Co., Midland, Mich., a 1950 graduate of University of Michigan.

Woodrum, Wilmer B., Quality Control Supervisor, Riegel Corp., Edinburg, Ind., a 1953 graduate of Virginia Polytechnic Institute.

Woodthorpe, Goeffrey L. H., Chief Chemist, Jointine Products Co., Ltd., Lincoln, England.

Wurtman, George S., Sales Engineer, Nichols Engineering & Research Corp., New York, N. Y., a 1952 graduate of New York University.

Appointments

Betty S. Allender, formerly technical director of Papelos Venezuelanos, is now with Fabrica Nacional de Papel Tissue Ltda., Santiago, Chile.

Kjell Aslund, formerly with Fiplasto S.A.C.I., is now Engineer for Laminas del Caribe, Barranquilla, Columbia.

John M. Behnke, formerly with Nopco Chemical Co., is now a Consulting Chemist, 185 North Munn Ave., East Orange, N. J.

Warren A. Beman, formerly with Socony Mobil Oil Co., is now Vice-President in Charge of Petrochemicals, Union Texas Natural Gas Corp., Houston, Tex.

Robert C. Berger of the General Electric Co. has been transferred from

SHARPEN
the image with
PURECAL® O

. . . the Key Chemical so uniform, it's unique

Purecal O particles are uniform in size and shape . . . ideal in size and shape to give paper coatings the smoothness for clean, quick acceptance of fine impressions. These special properties are all traceable to Wyandotte's unique precipitation process. No other produces calcium carbonate like Purecal O. Try it.

WYANDOTTE CHEMICALS

MICHIGAN ALKALI DIVISION, WYANDOTTE, MICHIGAN

Schenectady, N. Y., to Erie Pa., as Senior Application Engineer for the DCM & G. Dept.

Hans Bettschen, formerly of Empaques de Carton "United" S.A., is now with Beloit International, Zurich, Switzerland.

H. W. Bialkowsky, formerly of the Weyerhaeuser Co., is now assistant to the President of Stora Kopparberg Corp., New York, N. Y. Dr. Bialkowsky was formerly a member of the TAPPI Executive Committee.

De Wane A. Brenner, formerly of Watervliet Paper Co., is now Project Chemist for Simpson-Lee Paper Co., Vicksburg, Mich.

Booker P. Bunch is now Pulping and Chemicals Production Manager for the Mead Corp., Chillicothe, Ohio.

William T. Burns is now Technical Director of Bell Fibre Products Corp., Chicago, Ill.

John Carson is now Conversion Coating Production Manager for the Mead Corp., Chillicothe, Ohio.

Josiah Chapman, formerly of the Reed Paper Group, is now Head of Research and Development for Walmsleys (Bury), Ltd., Atlas Works, Bury, England

Perry J. Chase, formerly of the Keever Starch Co., is now Technical Adviser of Battelle Memorial Institute, Columbus, Ohio.

Otto M. Cline, formerly of the Niagara Corrugated Container Co., is now Plant Manager of Triangle Container Corp., Chicago, Ill.

Lewis B. Connelly, Sales Engineer for Eastman Chemical Products, Inc., has been transferred from Dallas, Tex., to New York, N. Y.

Paul B. Corning, formerly of Parsons & Whittemore, Inc., is now a Consulting Engineer located at the Cornell Club, New York, N. Y.

Lionel A. Cox, formerly of Johnson & Johnson, Ltd., is now Vice-President in Charge of Research and Development of Personal Products Corp., Milltown, N. J.

Thomas P. Czepiel of Scott Paper Co. has been transferred from Chester, Pa., to Winslow, Me., as a Special Products Engineer.

William J. Delaney is now Product Manager of Metalsalts Corp., Hawthorne, N. J.

David A. Finnegan, formerly Chief Engineer of Arkwright Finishing Co., is now with Photek, Inc., W. Kingston, R. I.

William A. Foster, formerly a Student at The Institute of Paper Chemistry, is now a Chemist with the Dow Chemical Co., Midland, Mich.

Norman G. Gaylord, formerly Vice-President of Western Petro-chemical Corp., is now a consultant with Gaylord Associates, New Providence, N. J.

John R. Gunning, formerly with Provincial Paper Ltd., is now Supervisor of Paper Research for Abitibi Power & Paper Co., Ltd., Sault Ste. Marie, Ont., Canada.

Carl L. Hackbarth, formerly with Grace y Cia, in Puerto Rico, is now an Engineer for W. R. Grace & Co., New York, N. Y.

Gilbert L. Hembree, formerly of Borden Chemical Co., is now a Sales Representative for Thiele Kaolin Co., Sandersville, Ga.

Warren E. Henricks is now Assistant Division Manager of the Mead Corp., Chillicothe, Ohio.

Thomas J. Henson of Thatcher Glass Mfg. Co. has been transferred from Elmira, N. Y., to New York, N. Y., as Central Packaging Director.

Kenneth B. Hill of the St. Joe Paper Co. has been transferred from South Hackensack, N. J., to Jacksonville, Fla., as Sales and Production Manager.

Maurice L. Hobday, formerly of Wakatane Board Mills, Ltd., is now Director of the Fletcher Trust & Investment Co., Ltd., Auckland, New Zealand.

Valdemar A. Jacobsen of the Ciba Co., Inc. has been transferred from Philadelphia, Pa., to Rumford, R. I.

Ralph K. Johnson of the Bailey Meter Co. has been transferred from Wickliffe, Ohio, to East Orange, N. J., as an Application Engineer.

Lawrence M. Joseph, formerly of United Paper Products Corp. is now General Manager of Gemayel Freres, Beirut, Lebanon.

Ferdinand E. Katzmyr, formerly of Container Corp. of America, is now Chief Chemist for Stein, Hall & Co., Inc., Paper Laboratory, Long Island City, N. Y.

Harold W. Knudsen is now Vice-President in Charge of Research of Hollingsworth & Vose Co., E. Walpole, Mass.

William D. Kohlins, formerly of Buflavok Equipment Division of Blaw-Knox Co., is now vice President in Charge of Operations of Podbielnick, Inc., Chicago, Ill.

Charles E. Lanyon is now Vice-President in Charge of Research for John A. Manning Paper Co., Troy, N. Y.

William P. Magowan, formerly Student at Lowell Technological Institute, is now Technical Service Engineer for Gilman Paper Co., Gilman, Vt.

Bernard E. Majani, formerly of Black-Clawson Co., is now an Application Engineer for Companhia Federale de Fundicao, Rio de Janeiro, Brazil.

Keith W. Max is now Director of Research and Development of the Containerboard and Kraft Paper Div. of Continental Can Co., Augusta, Ga.

Ralph E. McCallum, formerly of Celgar, Ltd., is now with Nova Scotia Pulp, Ltd., Port Hawkesbury, N. S., Canada.

Parker McIntosh, formerly of the KVP Co., is now Production Supervisor for Island Paper Mills, Annacis Island, New Westminster, B. C., Canada.

Vernon E. Moore of Becco Chemical Division has been transferred from Los Angeles, Calif., to Villa Park, Ill., as Midwest Manager.

Philip A. Peterson is now Chief Engineer of Rice Barton Corp., Worcester, Mass.

H. G. Psyras, formerly with Union Paste Co., is now the Manager of Adhesives Technical Service, Reichhold Chemicals, Inc., Elizabeth, N. J.

J. D. Reach, Jr. is now Pulp and Paperboard Div. Research Director for Weyerhaeuser Co., Everett, Wash.

Robert W. Reed is now Assistant Manager of Manufacturing for the Printing Paper Div. of St. Regis Paper Co., New York, N. Y.

Howard E. Rowan, formerly of Doeskin Products, Inc. is now Resident Manager of Steiner Tissue Mills, Albany, N. Y.

George F. Schuning of J. O. Ross Engineering Div. has been transferred from Boston, Mass., to New York, N. Y., as an administrative assistant.

Delbert B. Schuster, formerly of Caradco, Inc. is now a Research Assistant at The Institute of Paper Chemistry, Appleton, Wis.

Nicholas Shoumatoff, formerly with West Virginia Pulp & Paper Co., is now an executive Engineer in the Pulp and Paper Mill Product Div. of Lyddon & Co., Ltd., London W.1, England. Mr. Shoumatoff is vice chairman of the TAPPI Engineering Division.

George E. Soyka is now associated with Castillo y Soyka Sales Agency, Catolica 45, Mexico, D. F.

Gordon L. Sparks, formerly a Student at the Lowell Technological Institute, is now in the U. S. Army.

Earl E. Sproull, II, formerly of Riordan Sales Corp., is now a Salesman for Northeastern Paper Sales, New York, N. Y.

George Suydam is now Plant Manager, Case Brothers, Inc., Brattleboro, Vt.

Walter H. Swanson, Vice-President in Charge of Research for Kimberly-Clark Corp., has retired.

Frederick A. Szmit, formerly a Student at Lowell Technological Institute is now a research and development engineer for Spaulding Fibre Co., North Rochester, N. H.

Adalberto Tirado A. is now Pulp Mill Superintendent for Fabricas de Papel Loreto y Pena Pobre S.A., Villa Obregon, Mexico, D. F.

Alton P. Tracy is now Vice-President and Technical Director of John A. Manning Paper Co., Inc., Troy, N. Y.

Wallace Valentine, formerly of Vegetable Parchment Mills (Delcroix), Ltd., is now General Manager of Thos. Owen & Co., Ltd., Ely Paper Works, Cardiff, South Wales.

Bjorn E. Werenskiold, formerly of Canadian Vickers, Ltd., is now a Development Engineer for Foster Wheeler, Ltd., St. Catherines, Ont., Canada.

Jesse A. Weatherford is now Director of Sales for Virginia Chemicals & Smelting Co., W. Norfolk, Va.

Keith H. Williams, formerly a Chemist of Midstates Gummed Paper Co., is now a Consultant at 308 South Fordham, Aurora, Ill. Mr. Williams is a member of the Steering Committee of TAPPI.

* * *

Ross C. Wilcox, Vice-President of Research and Development, has succeeded *R. J. Sund* as the official corporate representative of the Marathon Division, American Can Co., Menasha. Wis., in the Technical Association.

M. A. Joglekar has succeeded *O. P. Varma* as the official corporate representative of Ballarpur Paper & Straw Board Mills, Ltd., Ballarpur, India, in TAPPI.

Warren E. Abramas has succeeded *A. W. Plummer* as the official corporate representative of the Hudson Pulp & Paper Co.. New York. N. Y., in TAPPI.

* * *

W. Donald Thompson has succeeded *Thomas S. Morse* as the official representative of Hercules Powder Co., Wilmington, Del., in TAPPI.

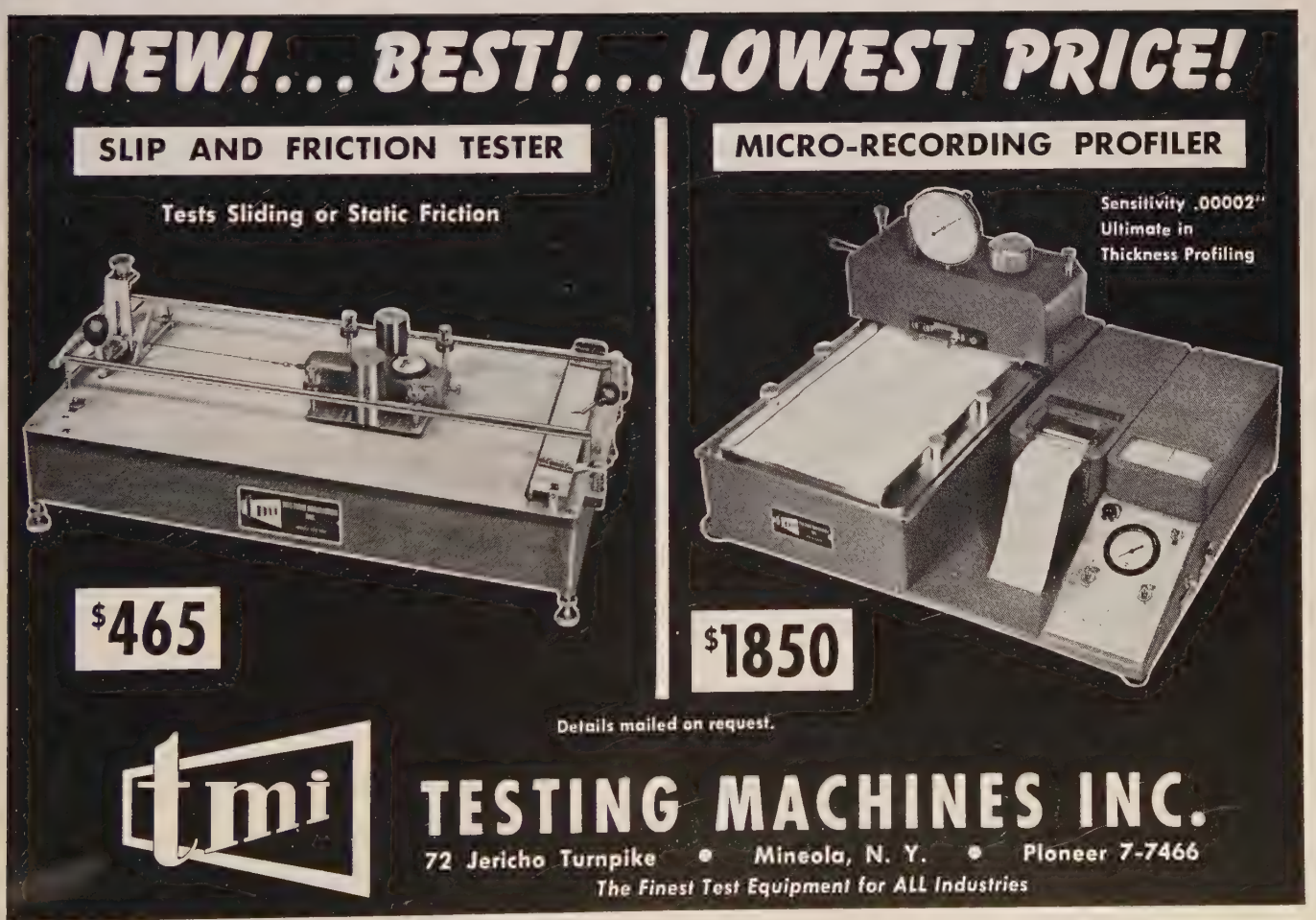
Howard W. Bartlett has succeeded *K. E. Fulton* as the official representative of Keever Starch Co., Columbus, Ohio.

Charles H. Horch, General Manager has succeeded *N. A. Seidensticker* as the official corporate representative of Chillicothe Paper Co., Chillicothe, Ohio, in the Technical Association.

The following issues of *Tappi* are available:

January to December, 1949	$0.75 per issue to members $1.00 per issue to nonmembers
January to December, 1950 (February out of print)	" " " " "
January to December, 1951	" " " " "
March to December, 1951 (January and February out of print)	" " " " "
January to December, 1953	" " " " "
January to December, 1954	" " " " "
February to December, 1955 (January, March, and August out of print)	" " " " "
January to December, 1956 (February and March out of print)	$1.00 per issue to members $1.50 per issue to nonmembers
January to December, 1957	" " " " "
January to December, 1958	" " " " "
January to December, 1959	" " " " "
January to December, 1960 (August, September, and October out of print)	" " " " "

Current issues are sent only to members of the Association. However, nonmembers may purchase individual back issues. Discounts are not allowed on these publications which are intended primarily for members of the Association.



INDUSTRY NOTES

Paper Manufacturers and Converters

Bowaters Carolina Corp.

Clarence H. Hornsby, Jr. has been named groundwood superintendent for Bowaters Carolina Corp. Mr. Hornsby was formally employed as assistant pulp mill superintendent by International Paper Co. at Pine Bluff, Ark.

Buckeye Cellulose Corp.

Buckeye Cellulose Corp.'s unique position, as the only producer in the industry manufacturing market pulp from both cotton linters and wood, focuses attention on the company's historic emphasis—and dependence—on research.

The initial production of cellulose by Buckeye came from the belief that there was a possibility of making a pulp suitable for paper from cottonseed hull fiber. Buckeye had supplied this material from its oil mills to producers of gun cotton during World War I. Production equipment was purchased in 1919, and it was early realized that research and development work was of major importance to the success of the undertaking. Ross Campbell, technical director of American Writing Paper Mills, was employed through an arrangement with American Writing to take charge of the Buckeye laboratory and experimental and development work.

From this early beginning, Buckeye research has led the way to production of increasingly pure and improved cellulose from second cut linters, first cut linters, and wood. Buckeye's growth and success have been a direct result of a long history of research.

Foley: The Mill That Research Built

After more than 30 years of research and development in the production of cotton linter pulps, Buckeye made its entry into the related field of wood pulp production. Research led the way. Years of experience in Buckeye Cellulose's Memphis laboratories had led to the development of a new sulfate process for making pulp from pine. The new process made possible pulps superior to the current standards, and Buckeye built its wood pulp plant at Foley, Fla.

In producing its complete line of bleached kraft and highly specialized dissolving pulps, the Foley plant employs a unique, flexible, eight- to eleven-stage bleaching process developed by Buckeye research. Since its installation in 1954, the process has been continually improved, and although details on this process are considered confidential, Buckeye believes that it is the only company in the industry using this improved technique.

Research Facilities

Extensive research has been a major factor in the rapid growth that has tripled Buckeye's productive capacity in recent years. To keep pace, the company's research facilities have been quadrupled since 1952.

Headquarters for Buckeye's research and development activities is a large, modern laboratory, built in 1953, and one of the largest and most complete research centers in the pulp industry. With company growth, broadened research efforts have made necessary a 60% expansion of the Center—from its original 31,000 sq. ft. to more than 50,000 sq. ft. The staff now numbers more than 200 people.

Activities at the Center include both basic and applied pulp studies, as well as research on chemical derivatives and by-products. Specific research projects are directed toward: (1) improved processes of manufacture and control, (2) uses for by-products of the pulp-making process, and (3) finding new end-uses for pulp products.

In addition to basic and applied facilities, the Memphis Center includes a separately-housed pilot plant for cellulose products in which research findings can be applied in the production of quantities up to two tons per day. For example, before the original Foley mill was built, the Foley process developed in the laboratory was put to the test of actual production, using logs shipped to Memphis from Florida. This pilot plant is believed to be the largest of its kind in the industry. Other pilot plants in Memphis duplicate both Buckeye processes and customer end-use processes on scales ranging from $^1/_{3000}$ to $^1/_{20}$ of actual size.

Three-Way Research Program

Today's research in cellulose and cellulose chemistry at Buckeye continues work underway since 1920 in three general categories:

1. *Fundamental Research.* Over the years results have increased general knowledge in the field and led to a much better understanding of basic pulp problems. In turn, findings have led to the development of better processes and products so improved that they would have been considered impossible years ago. Examples are paper pulps with improved strength, brightness, greater uniformity, and significantly greater cleanliness.
2. *Process Development Research.* Each production step is studied with particular emphasis on the effects of all variables. This information establishes the best processing methods, and provides the basis for standardized procedures in plant operation and the closest possible control of product quality.
3. *Customer Research.* Since pulp is an intermediate in the manufacture of many products, it must perform correctly in the varying processes used by Buckeye's numerous customers in the different fields. For this reason, Buckeye maintains extensive equipment in order to study problems involved in pulp end-use. Numerous pieces of specialized testing equipment are in constant use on comparative studies.

In addition to the facilities at Memphis, studies on special projects are supplemented by work at the basic research center of Buckeye's parent company, Procter & Gamble. Buckeye also sponsors reasearch and development studies at independent laboratories such as The Institute of Paper Chemistry, Cellulose Research Institute, and leading universities.

Swedish Research Project

Currently, for example, Buckeye is sponsoring a unique research project at the University of Uppsala in Sweden. Aspects of the three-year project include the study of pulp molecular properties in certain solutions, and the relation of molecular sizes and shapes to types of pulp and methods of processing.

Ultimately, the fundamental information developed in this project will help guide pulp producers toward more precise tailoring of pulps to specific end-uses. In addition, manufacturers of cellulose-based products should be able to apply the findings to their processes to improve product performance.

Columbia Cellulose Co., Ltd.

A. E. Penney has been appointed executive vice-president of Columbia Cellulose Co., Ltd. and Celgar, Ltd., according to an announcement by T. N. Beaupré, president. Mr.

A. E. Penney, Columbia Cellulose Co., Ltd.

C. D. Bown, Columbia Cellulose Co., Ltd.

Penney joined Columbia Cellulose and Celgar in 1956 and has previously held the position of vice-president, Pulp Manufacturing.

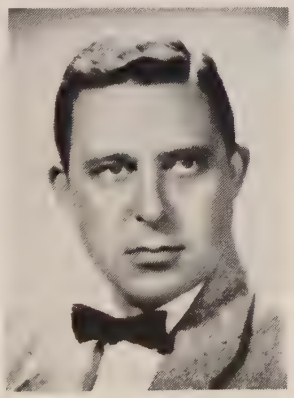
Columbia Cellulose has also recently announced the appointment of C. D. Bown to the position of assistant technical superintendent. Mr. Bown joined the company's Prince Rupert mill in 1951 as a tester in the cellulose acetate pilot plant and since 1958 has held the position of plant chemist. In his new post he will direct the activities of the acetate and viscose pilot plants and the main and control laboratories, assist in the formulation and execution of the process engineering program, and coordinate mill production with sales.

Container Corp. of America

Alfred F. Mooty has joined the Agricultural Packaging Div. of Container Corp. of America. He will work with both domestic operations and the Foreign Division, assisting in technical development of corrugated containers for banana shipments. He also will aid in developing other types of produce packaging.

Continental Can Co.

Keith W. Max will assume the newly-created position of director of research and development for the Containerboard and Kraft Paper Div. of Continental Can Co., it was announced by C. B. Stauffacher, executive vice-president of the Robert Gair Paper Products group. Dr. Max and his staff will be located in the company's new bleached board mill at Augusta, Ga.



Keith W. Max, Continental Can Co.

K. M. Lewis has become manager of the Chicago paper products plant of the Bondware Div., Continental Can Co. Formerly assistant plant manager at this location, Mr. Lewis replaces R. Drotziger, who retired in February.

The Chicago plant is located at 4711 W. Foster Ave. and manufactures single wrap cold drink cups, cone cups and compatible lids, for water, ice cream, sundaes, and sodas.

Consolidated Water Power & Paper Co.

Ward J. Anderson has been appointed power superintendent for Consolidated Water Power & Paper Co. and Wisconsin River Power Co., it was announced recently by M. V. Molsberry, Consolidated's manager of power and president of Wisconsin River Power Co. He succeeds the late E. E. Belter.

Crown Zellerbach Corp.

Crown Zellerbach Corp. has signed an option agreement with the Noguchi Institute of Tokyo, Japan, for the exclusive American and Canadian rights to the Institute's process for the hydrogenation of lignin from wood pulp spent liquors, it was announced recently by W. M. Hearon, Crown Zellerbach vice president for research and development.

Lignin, which is one of the principal constituents of wood, is currently largely discarded as waste or burned at most pulp mills. It has been the subject of a great deal of research in an attempt to develop large-scale commercial uses.

Under the hydrogenation process developed by Noguchi as the result of years of intensive research, lignin can be separated into a number of compounds which have a considerable potential utility as raw materials for the synthetic organic chemical industry. For the past two years, Noguchi has successfully operated a small pilot-plant and is currently planning an enlarged pilot operation in Tokyo with a daily capacity of 2200 lb.

The Noguchi process produces a number of phenolic compounds and neutral oils. Projected markets for these products include such items as agricultural chemicals, resins, additives for petroleum and rubber products, disinfectants, plasticizers, antioxidants, and adhesives.

The Noguchi Institute believes that phenolic compounds can be produced less expensively from lignin than from coal tars and petrochemicals. Furthermore, lignin from either of the two major pulping methods, sulfite or kraft, can be used in the process, as well as the lignin left after the hydrolysis of wood to produce sugars.

The Noguchi Institute, a privately endowed research organization founded in 1941 and supported by Japanese industrial firms, has devoted 14 years to various research studies on wood chemicals.

Under the terms of the Crown Zellerbach-Noguchi agreement, Crown Zellerbach will evaluate the Noguchi lignin liquefaction process during the option period, and acquires the right to obtain an exclusive license in the United States and Canada for the process on a royalty basis. Crown Zellerbach would also have the right to sublicense the process to other companies in the United States and Canada.

Crown Zellerbach's Chemical Products division pioneered the production of dimethyl sulfide from kraft spent liquors at Camas, Wash., and is currently producing lignin sulfonate Orzan products from sulfite spent liquors at Lebanon, Ore., and dimethyl sulfide, dimethyl sulfoxide, and methyl mercaptan from kraft liquors at Bogalusa, La., as well as tall oil and sulfate turpentine at Bogalusa and sulfate turpentine at Port Townsend, Wash.

Doeskin Products, Inc.

Morton J. Harris has been promoted to general manager of the Utica Div. of Doeskin Products, Inc., it was announced recently. Mr. Harris takes the place of Howard Rowan, former general manager who recently left the organization to take a similar position with Steiner Tissue Mill of Albany, N. Y.

Doeskin maintains two additional locations; one at Rockland, Del., and one at Clayville, N. Y.

Downingtown Paper Co.

An unusual booklet entitled "Paperboard Production" has recently been prepared by the Downingtown Paper Co. The story of paperboard manufacturing, from the blending of raw materials to the shipment of the finished product, is coordinated with photographs of the actual processes in ac-

tion. Pointed out in the booklet is the fact that "Man's culture has been set down on paper, wrapped in paper and bookbound in paper for many centuries. Today, paper packages everything from doughnuts to business deals . . . it makes mass education and world communications things that are taken for granted."

"Paperboard Production" is available upon request, compliments of the Downingtown Paper Co., Downingtown, Pa.

John A. Manning Paper Co.

James F. Adams, chairman of the Board of the John A. Manning Paper Co., Inc., Troy, N. Y., has announced the election of Albert H. Miller as president and chief executive officer of the company. Mr. Miller took over his new duties the first of May. He was formerly president of Lewis-Brownville Sales, Inc., which is affiliated with The J. P. Lewis Co., Beaver Falls, N. Y., and before that was with Kimberly-Clark Corp., Neenah, Wis.

John A. Manning Paper Co., Inc., was established in 1846. They have mills in Green Island, N. Y., and Troy, N. Y., with five production machines and two development and research machines. Their principal production is in rope papers of great strength and other industrial specialties made from rope, rag, wood, and sundry fibers. The chief grades are electrical insulating papers and board, abrasive backing, saturating, filter, gasket, and other specialty items.

Mead Corp.

Chillicothe Division

Promotion of five management and production employees at The Mead Corp.'s Chillicothe Division and the retirement of E. B. Brundige as production manager have been announced. Warren E. Henricks has been named assistant division manager; Mason Hinkle, production manager, paper machines; William Berthold, production manager, finishing, shipping, specialty products; John Carson, production manager, conversion coating; and Booker Bunch, production manager, pulping and chemicals.

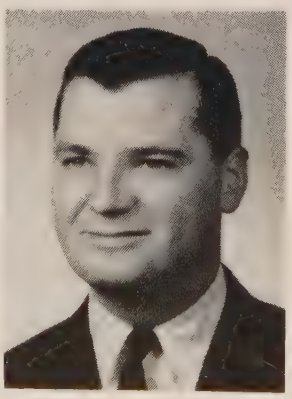
Russell E. Vannatta, plant manager of The Mead Corp.'s Cincinnati Div. for the past 8 years, has been promoted to division manager.

Nicolet Paper Co.

Nicolet Paper Corp., has developed an aluminum coated glassine paper, made in continuous mill roll lengths by a newly-perfected process. The continuous vacuum coating equipment used by Nicolet was designed and built by F. J. Stokes Corp., Philadelphia.

Northeastern Paper Sales, Inc.

Announces the appointment of Earle E. Sproul, II to its pulp sales division. Mr. Sproul was previously with Riordon Sales Corp., Ltd. His new position will have Mr. Sproul responsible for pulp sales in the mid-western and mid-Atlantic states. Northeastern Paper Sales, 400 Madison Ave., New York, N. Y., is the exclusive sales representative for Gaspesia Sulphite Co., Ltd. and Anglo-Newfoundland Development Co., Ltd.



E. E. Sproul, II, Northeastern Paper Sales, Inc.

Packaging Corp. of America

Clinton W. Tasker has joined Packaging Corp. of America as director of technical research and development and will be located in Grand Rapids, Mich.

Dr. Tasker formerly was with the Film Div. of the American Viscose Corp. at Fredericksburg, Va. He has 19 years experience in the cellulose, chemistry, and film processing field.

Potlatch Forests, Inc.

Potlatch Forests, Inc., Lewiston, Idaho, has announced commercial availability of a new type of high barrier paperboard which the company says makes a strong bid to extend the uses of paperboard in its competition with plastics, metals, and glass in many areas of modern packaging.

Potlatch is the first United States paper manufacturer to produce the high barrier board in commercial quantities. Plans call for early production of high barrier papers as well.

Clearwater unit of Potlatch Forests at Lewiston, Idaho, where new high barrier paperboard is being produced

The company said the new paperboard provides the packaging industry with an economical material which has high resistance to moisture, grease, air, gases, ordors and many acids, alkalies, and solvents. Packages made of it help to retain the original freshness, aroma, and flavor of good products.

Eventual applications for the new Potlatch products span a wide range. In good packaging, the possibilities run from cookies, cereals, and dehydrated soups to fresh and frozen foods and mustard, sauces, syrups, and milk. For general industrial use, the range is from motor oils to cement, fertilizer, seed, chemicals, photographic film, and pharmaceuticals. In the specialty packaging field, the new papers and board may package such products as cosmetics, shampoo, soap, and tobacco products.

Potlatch Forests is one of the country's leading producers of lumber and lumber products, pulp, paper, and paperboard. As a paperboard producer, the firm has grown to top ranks within the last 10 years. The company is known for its prompt adoption and marketing of paperboard innovations.

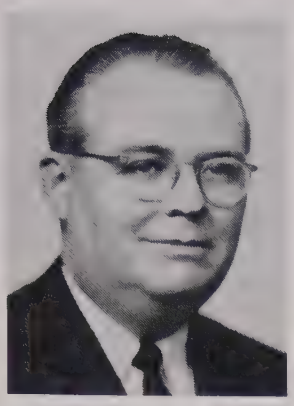
Rayonier Inc.

A new industrial raw material resulting from the highly uniform grafting of an organic compound to the cellulose polymer and representing a significant advance in cellulose chemistry was shown at the Eastern Research Division of Rayonier Inc.

Trade-named "Ethylose," the new material, an outgrowth of the chemical cellulose producer's graft polymer program, is seen by company officials as only the first in a whole family of modified celluloses in which various chemicals and polymers are grafted onto a basic cellulose backbone.

The company is hopeful that the new material will broaden

L. J. Forrest, Rayonier, Inc.



Michael A. Brown, Rayonier, Inc.

and further diversify the uses for cellulose, a readily available and easily replenishable low-cost chemical from trees. Potential markets of special interest include coated papers, textiles, paints, ceramics, and foods. Rayonier research said it foresees such immediate new products as textile sizes, binders, and coatings.

"Ethylose" is a high-quality, purified wood cellulose modified or grafted with a small amount of ethylene oxide to alter its behavior characteristics. It is insoluble in water. Up to 8–12% "Ethylose" can be dissolved in a solution of 5% or more of a sodium hydroxide (NaOH) concentration. Other bases, he said, such as potassium hydroxide and lithium hydroxide can also be used. The Rayonier graft cellulose is also soluble in the common cellulosic solvents such as cuprammonium hydroxide, cupriethylene diamine, ammonium thiocyanate, sodium ferric tartrate, Cadoxen, etc. "Ethylose" swells slightly in quarternary ammonium compounds and is insoluble in nearly all organic solvents, as well as water.

"Ethylose" solutions can be adjusted to proper solids-viscosity ranges for coating, tub sizing, or surface spraying. "Ethylose" can be regenerated by alkali removal or heat followed by washing. The particular method selected will depend on the process and end-use requirements. Neutralization can be accomplished by acid-salt solutions such as 10% H_2SO_4 and 15% Na_2SO_4, or by acid alone. Acid-salt solutions of a dehydrating nature regenerate a product with higher density, lower gel swelling, and best physical strength, he said. Temperatures in the range of 40 ± 60°C. are preferred.

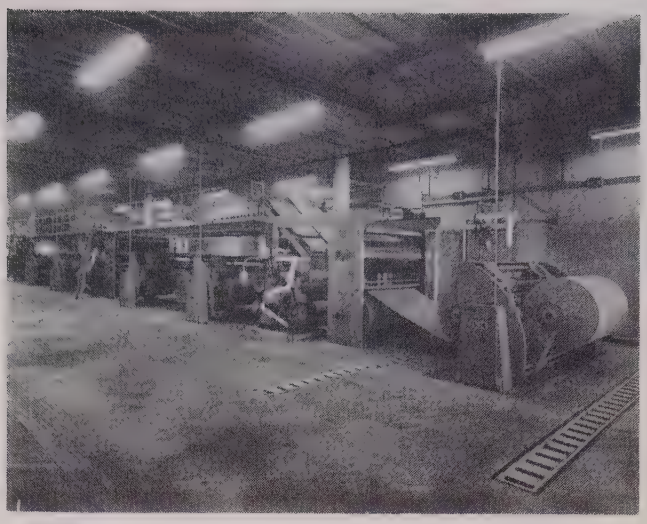
At the same time it was announced that the company had recently placed in operation a new plant at its Fernandina Beach, Fla., divison for the manufacture of the new material. It was reported that the "Ethylose" plant was using a continuous, automated process employing new concepts in both reaction principles and in equipment designs. Details cannot be disclosed at this time because patent coverage is being sought.

Officers

L. J. Forrest and Michael A. Brown have been elected vice-presidents of Rayonier, Inc., the chemical cellulose producer. Mr. Forrest manages the Northwest Timber Division and becomes the company's ranking executive in the Pacific Northwest. Mr. Brown is in charge of sales with headquarters at New York.

Royal Container Co.

A giant step forward to meet the rapidly accelerating demand for corrugated packaging was demonstrated at the newly completed plant of Royal Container Co.—Southern California, Buena Park, Calif. This dramatic advance has come in the form of a new facility for the production of corrugated paperboard boxes—in which every component from



Feed end of block-long Corrubiner at new Royal Container plant includes the single facing section which joins fluted center section of the corrugated board with one of the smooth faces

the feed to delivery end has been so integrated as to form a single operational unit.

Designed and built by S & S Corrugated Paper Machinery Co., Inc., Brooklyn, N. Y., the new unit—known as the "Corrubiner"—is designed to satisfy the competitive requirements of modern high-speed production, brought about by the greatly increased use of corrugated boxes as finished packages and displays in contrast to purely functional shipping containers.

St. Regis Paper Co.

St. Regis Paper Co. announces the appointment of R. W. Reed as assistant manager of manufacturing of its Printing Paper Division. In this position, Dr. Reed is directly responsible for the operation and administration of the printing paper mills. He reports to L. J. Smith, manager of manufacturing for the mills of this division.

Coincidently with this change, the functions of Technical Service to Customers, Quality Control, and Mill Sales-Service for the Printing Paper Division have been transferred from the Technical Division to the Printing Paper Division. Harvey E. Sweetland becomes manager of Customer Services of the Printing Paper Division.

American Sisalkraft Co.

Two new high-speed laminating and reinforcing machines for converted paper products are planned for full operation in two American Sisalkraft Co. plants this year. The main plant in Attleboro, Mass., has completed installation of one machine which is designed primarily for the manufacture of reinforced tape base stock and Pyro-Kure flameproof vapor barriers. This new machine will employ glass, rayon, and other synthetic fibers in a variety of reinforcing patterns, in widths up to 60 in. Regular production runs are now being scheduled for this equipment.

The other new machine will be installed at Sisalkraft's Cary, Ill., plant sometime this year. This new high-speed laminator will be used primarily to produce tape grades in wide widths at higher speeds with improved quality control. This additional production equipment will offer Sisalkraft's midwest customers a more diversified line of products in addition to better service.

American Sisalkraft Co. produces plastics, reinforced papers, vapor barriers for the building and packaging industries and tape base stock for the gummed paper industry.

Rhinelander Paper Co.

A new continuous bleach plant designed for a maximum of 120 tons per day began operating recently at the Rhinelander, Wis., mill of St. Regis Paper Co.'s Rhinelander Paper Co. Div.

The new bleach plant is designed to provide brighter and whiter pulps for the expanding markets of glassine and greaseproof papers. Construction of the nearly $1-million plant began in February, 1960, on the site of the plant's former bleach liquor plant.

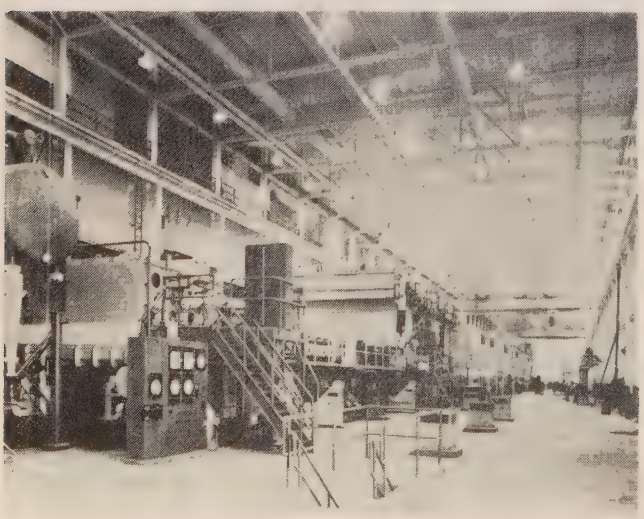
The three-stage continuous bleaching process for 85% G.E. brightness pulps used in the new plant was first tested in the plant's research department. Research findings showed the process to be practical, economical, and capable of providing a very high quality pulp. These findings were confirmed in the old plant under conditions simulating the proposed continuous process. The experimental pulps were used in the manufacture of a broad range of Rhinelander papers and proved to be excellent in strength, brightness, hydrating qualities, cleanliness, and color.

Chlorination is conducted at a 3% consistency in the first stage. In the second stage, caustic extraction is conducted at 3% consistency or as an alternate method at 12% consistency. Hypochlorite is conducted at 12% consistency in the final stage of the bleaching sequence.

Unbleached blending and storage are provided ahead of the first stage by two 15-ton storage chests at 6% consistency. Ahead of the chests, water extractors thicken the screen room stock to the proper storage consistency. The second stage is unique in that the flow through the tower can be run at either a high consistency (12%) downflow stage or as a low (3%) upflow. Centrifugal cleaners were installed between the hypochlorite stage and the final washer.

The new building which houses the bleach plant measures 90 ft. in width by 80 ft. in height, and was constructed of structural steel with exterior walls of insulated transite. Fiberglas was used extensively in the new facility. Both the caustic and chlorine stage washers have ventilation hoods fabricated of the material, and fiberglas piping was installed on all chlorinated stock lines.

The production of the many grades of Rhinelander bleached pulps is controlled through a main control panel located on the washer floor. The panel provides control of all stock and chemical flow rates, stock levels, washer operations, consistencies, and the distribution and storage system. The panel is housed in a pressurized room conveniently located for visual control of the washer floor which permits easy instrument confirmation and exceptionally quick response to changes and operating variables.



Scott Mobile no. 9

Scott Paper Co.

Scott Paper Co. announced the start up of a new, high-precision paper machine for the manufacture of cultural grades such as lightweight printing and offset papers at its Southern Division plant in Mobile, Ala.

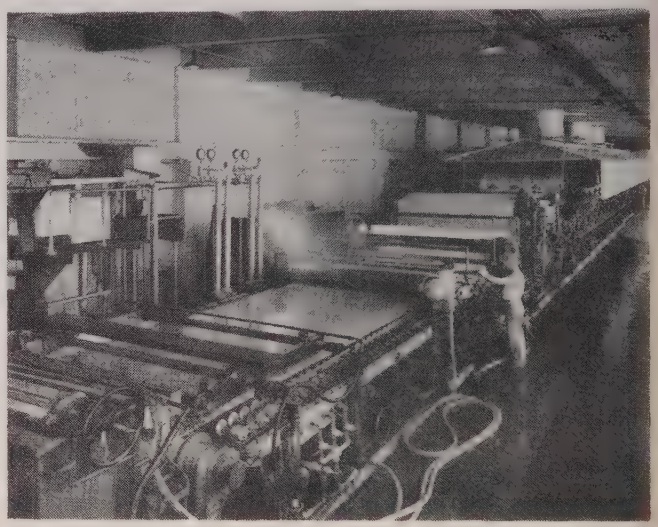
The company invested more than $20,000,000 in the machine and supporting facilities. No public financing was directly involved in the two-year expansion program.

Scott Mobile no. 9 has three stations where special precoatings can be applied. The machine was designed by Scott engineers in conjunction with Beloit Iron Works.

The expansion program will add approximately 300 people to Scott's work force of 1650 at Mobile, and some $1,750,000 to its payroll which is currently at the annual rate of $11,000,000. The company's purchases of pulpwood are expected to increase by more than $2,000,000 to $8,750,000 annually.

Strathmore Paper Co.

The Strathmore Paper Co. has announced that it will completely rebuild its no. 6 papermaking machine in Woronoco late this summer. The machine, one of three at the Woronoco mills, produces bond, blueprint, tracing, diazo or white print, and photographic base papers.



Strathmore Paper Company's no. 6 machine in Woronoco, Mass., scheduled for complete rebuilding this summer. The new no. 6 machine will have a maximum speed of 750 f.p.m., approximately 50% higher than current speed. Total cost for the new machine, and the new power plant recently completed in order to operate at the new capacity, will be in the neighborhood of 2½ million dollars

Strathmore recently completed its new power plant in Woronoco, built to handle the increased capacity of the new machine.

Company officials estimate that by the time the no. 6 machine is completed, Strathmore will have spent close to $2,500,000 on these Woronoco installations.

When the rebuilt 250-ft. long machine is completed later this year, Strathmore will have spent almost $10,000,000 since 1953 on the modernization of plant and production facilities at its four locations.

The Manchester Machine Co. of Middletown, Ohio, has been given the contract to design the new machinery according to Strathmore specifications. It is anticipated that all of the equipment will be available by mid-August, and Strathmore officials plan to complete the installation within six weeks, working on an around-the-clock basis. The machine is being redesigned to make paper at a top speed of 750 f.p.m., compared with the present maximum of 500 f.p.m. As part of the complex rebuilding operation, the wire length of the fourdrinier is being increased from 50 to 75 ft., and 13 new drying drums and a new machine sizing unit will be added. The

new machine, when finished, will be approximately 60 ft. longer than its current counterpart. Improvements are also being planned in the preparation of stock used to make the paper.

Strathmore, with 900 employees, has the most extensive range of highest grade fine papers made by any mill in the country. Its products include bond and writing papers, text and cover papers, vellum papers and bristols, ledger and thin papers, and artist and technical papers.

Weyerhaeuser

Shipping Container Division

The appointment of Howard L. Simmons to the newly created position of vice-president-manager of Weyerhaeuser Co.'s shipping container division was announced. He will take charge of the four regions which have headquarters in Camden, N. J., Chicago, Ill., San Francisco, Calif., and Charlotte, N. C.

Continuing as vice-president-coordinator of the shipping container division will be E. K. Radke.

Morgan also announced that William A. Wurster has been appointed to the newly created position of vice-president of the shipping container division's western region. Wurster has been serving as assistant to Morgan with headquarters at Tacoma.

Pulp and Paperboard Division

The appointment of J. D. Reagh, Jr., as research director of Weyerhaeuser Co.'s pulp and paperboard division was announced by Howard W. Morgan, group vice-president. Dr. Reagh joined Weyerhaeuser Co. in 1950 as research supervisor at the Longview research center. Since 1954 he has been associate director of the division's research department at the company's Everett branch.

Longview

Weyerhaeuser Co. has announced six promotions in the Longview branch of its pulp and paperboard division.

T. W. Stewart, superintendent of power for the Longview branch since 1947, was named to a newly created position of maintenance and engineering manager. Mr. Stewart, formerly employed at Weyerhaeuser operations in Everett, will complete 35 years of service with the company in May.

William M. Nanney, assistant superintendent of power since 1956, will replace Mr. Stewart. Edward Koeppen, shift engineer, becomes assistant superintendent of power.

Richard H. Cordingly, who joined Weyerhaeuser in 1958 following graduation from The Institute of Paper Chemistry, was promoted to assistant technical director of paperboard operations.

Harry A. Brown, assistant to the paper mill superintendent, and Edward Karnoski, paper mill foreman, were named assistant paper mill superintendents.

Educational Institutions

Institute of Paper Chemistry

Van den Akker Receives Fulbright Lectureship Award

J. A. Van den Akker, senior research associate and chairman of the department of physics and mathematics at The Institute of Paper Chemistry (Appleton, Wis.), has been invited by the University of Manchester, England, to be a lecturer in physics during the 1961–62 academic year, and has been granted a Fulbright award for this purpose.

Beginning October 1, Van den Akker will present at the University a series of lectures and seminars on the physics of paper, dealing with the theory and phenomena relating to paper's physical and optical properties. The appointment will end April 1, 1962.

In his position as head of the physics group at The Institute of Paper Chemistry, Van den Akker has made significant and continued contributions to the application of the principles of physics to research on the structure and properties of paper. He is widely known for work in instrumentation research and development of methods for measurement of both physical and optical properties of paper, especially in the areas of spectrophotometry and color measurement.

J. A. Van den Akker, The Institute of Paper Chemistry

Natural Hybrid Tree of Bigtooth Aspen and Silver Poplar

The locating and identifying in Wisconsin of a natural hybrid tree resulting from the crossing of a bigtooth aspen and a silver poplar has been announced by Dean W. Einspahr, research associate and forest geneticist in the biology group at The Institute of Paper Chemistry (Appleton, Wis.).

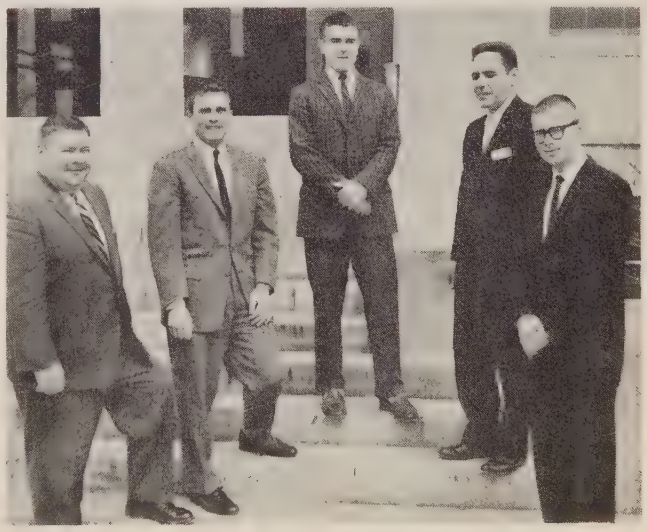
Approximately ten other similar natural hybrids have been reported. They have been found in southeast Iowa and in Canada. Unlike the previously reported trees, the Wisconsin tree bears both male and female flowers and will be useful in several types of genetic studies.

Of interest concerning the tree is its growth rate. Einspahr reports it to be 17 yr. old with a height of 70 ft., and a diameter of 13.7 in. at a height of 4.5 ft. above the ground.

NSF Fellowship

Paul A. Johnson, a doctoral candidate in the graduate school of The Institute of Paper Chemistry, has been awarded a Cooperative Graduate Fellowship by the National Science Foundation. The Fellowship is "cooperative" in that application for it must be made through a graduate school of the student's choice.

The Fellowship will mean an award from the National Science Foundation to Johnson of $1650 for a 9-month period. The graduate school of the Institute will receive from the



Dean of Students Richard W. Ivers, far left, and Dr. Dominick A. Sama, head of the Department of Chemical Engineering and Paper Technology at Lowell Technological Institute, next to him, are shown with three recent scholarship winners, left to right: Bernard Coyle, '61, and Peter Dubey, '62, recipients of $150 each from the Boston Paper Trade Association, and David Conley, '63, who received the New England Paper Merchants Association scholarship

Fellowship an award to cover all tuition and fees for Johnson's study for the 9-month period.

North Carolina State College

Jimmy Douglas Gregory of Route 2, Angier, has been awarded a $4000 scholarship by the Continental Can Co. for study in North Carolina State College's School of Forestry. The scholarship award was made by A. L. Wenrich of Hopewell, Va., district manager, Woodlands Division of Continental Can Co. This is the fourth consecutive year in which this scholarship has been awarded at State College.

Jimmy Douglas Gregory accepts scholarship to North Carolina State College from A. L. Wenrich, Continental Can Co.

Syracuse

Forestry and the atomic age of the 20th century have come together! The State University College of Forestry at Syracuse University, observing its 50th anniversary this year, announced that a new 1000-curie, cobalt-60 source for use in radiation research has just been installed at the college.

The cobalt-60, a radioisotope capable of emitting an average of 1.25 Mev (million electron volts) gamma rays, will be used by the college as a source of energy in chemical reactions. The source located in a concrete chamber adjacent to the basement of the Hugh P. Baker Memorial Wood Products Laboratory building, will be part of the research facilities of the Forest Chemistry Department, Dr. Conrad Schuerch, chairman.

The cobalt source and associated equipment were obtained by the College of Forestry through a grant from the Atomic Energy Commission (AEC), Washington, D. C.

Under the AEC grant, Drs. Vivian Thomas Stannett, John A. Meyer, and Michael M. Szwarc, who will be project directors, will direct research on ionic polymerization. Dr. Stannett is professor of polymer chemistry; Dr. Meyer, assistant professor of radiochemistry; and Dr. Szwarc is research professor of physical and polymer chemistry.

The Atomic Energy Commission has granted a special license to the college's Radioisotope Committee for possession of the cobalt-60 source. The Forestry College also has been granted an AEC license to possess various other radioisotopes for use in other research projects.

50-Year History of Forestry College

The Alumni Association of the State University College of Forestry at Syracuse University has published a 50-year history of the college entitled, "Forestry College: Essays on the Growth and Development of New York State's College of Forestry."

The date of publication for the book was April 12, the same day as the college began a three-day golden anniversary celebration (April 12, 13, and 14) at its campus.

Research Project

Conrad Schuerch, Jr., professor and chairman, Department of Forest Chemistry, State University College of Forestry at Syracuse University, has just been awarded a research grant of $12,430 by the Public Health Service, U. S. Department of Health, Education and Welfare, National Institutes of Health. The one-year grant becomes effective April, 1961, and continues through March, 1962. During the 12-month period, Dr. Schuerch, as project director, will direct a special study entitled, "Addition Polymerization of Anhydro Sugars to Dextrans."

The research project has been approved by the Surgeon General of the United States, upon recommendation of the National Advisory Health Council.

Industry Suppliers

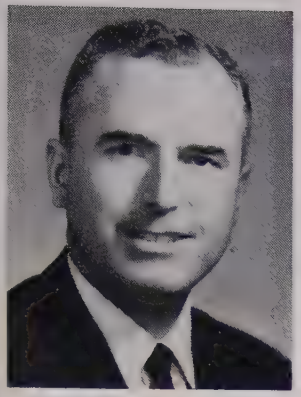
Albany Felt Co.

Albany Felt Co., Albany, N. Y., announced the appointment of Everett C. Reed as president of the multiplant operation. He succeeds John C. Standish who will continue as chairman of the board of directors. Other promotions announced were: Z. J. Chagnon and J. Spencer Standish to executive vice-presidents; Albert C. Cramer, vice-president (he will retain his post as assistant to the president), and Douglas P. Bridge as secretary.

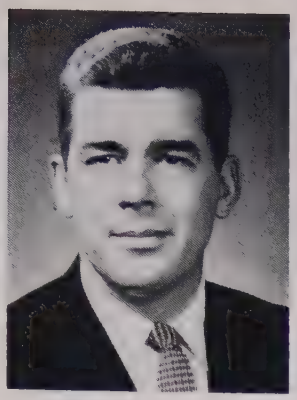
Albany Felt is a leading manufacturer of felts for the paper industry and other specialized industrial fabrics. Plants are located at Albany and Hoosick Falls, N. Y., North Monmouth, Me.; St. Stephen, S. C.; and foreign subsidiaries in Cowansville, Que.; and at Cuautitlan, Mexico. It also has a minority interest and working agreement with Nordiska Maskinfilt A. B. Halmstad, Sweden—one of the largest European felt manufacturers.

Albany Felt Co. has also announced the appointment of Robert Sloan as manager of felt operations within the United States. He will assume responsibility for the St. Stephen, S. C., and Hoosick Falls, N. Y., operations as well as serving as plant manager at Albany, N. Y. Wayne Fry will continue as plant manager of St. Stephen.

Left to right are Albert C. Cramer, new vice-president; John C. Standish, board chairman and retiring president; Everett C. Reed, newly elected president; Z. J. Chagnon and J. Spencer Standish, named as exceutive vice-presidents, and Douglas P. Bridge, newly elected secretary



Robert Sloan, Albany Felt Co.



W. A. Goodwin, Albany Felt Co.

William A. Goodwin was recently appointed sales engineer for the Albany Felt Co., Albany, N. Y. He will service the company's paper mill customers in Virginia, North Carolina, and parts of Maryland, Tennessee, and West Virginia.

Louis Allis Co.

The Louis Allis Co., Milwaukee, Wis. recently announced (Bull. No. 3700) the addition of "Capsulex" insulation system, that has been especially developed for encapsulated formed coils used in large a.c. motors ranging in sizes from 200 to 2000 hp. The new insulation system provides added protection to windings against moisture, chemicals, oils and abrasive contaminants, allowing increased life for open motors used in unfavorable environmental conditions.

Allis-Chalmers Mfg. Co.

Appointment of Roy M. Casper as general manager, Power Equipment Division, effective May 1, has been announced by Allis-Chalmers. He succeeds J. W. McMullen, who is retiring after some 45 years of service with the company. Casper, who is a vice-president of the company, has been general manager, Atomic Energy Division since 1957.

VACU-THERM SYSTEM

The Vacu-Therm system for paper machine use is described in new literature (16B9954) released by Allis-Chalmers, Milwaukee, Wis. Consisting of a centrifugal exhauster, vacuum controls, and water separation equipment, advantages of the system, which provides preset constant pressure over a wide range of volumes, are described in the literature.

American Bitumuls & Asphalt Co.

Detailed information on Bitusize B emulsified asphalt size is described in a new booklet (B-30) prepared by the American Bitumuls & Asphalt Co., 320 Market St., San Francisco 20, Calif. Described as a highly stable liquid emulsion made from selected and specially processed asphalts, Bitusize B is recommended for use as a paperboard and structural insulation board sizing where water resistance is desired. Tabulated and other data are included to provide information on technical properties and features of storage and use.

American Marietta Co.

A new resin plant has been opened by the Adhesive, Resin & Chemical Div. of the American-Marietta Co. in Richmond, Calif. The new plant is designed for the production of synthetic resins to be used in the manufacture of plywood, paper, composition boards, laminates and other wood products, foundry cores and shell molds, mineral wool. It incorporates one of the largest chemical reactors in the industry, capable of producing up to 6000 gal. of resin in a single batch.

Babcock & Wilcox Co.

The Babcock & Wilcox Co. reported shipment of the first magnesium oxide (MgO) recovery system sold for installation outside of the United States.

The 734 ton B&W shipment left New York aboard the *S.S. Matilda Thorden* for a new pulp mill being erected in Ivetofta Parish, Sweden, by Nymolla Aktiebolag, a newly formed subsidiary of Hylte Bruks Aktiebolag. The plant is scheduled for operation in 1962.

The recovery system will process 560,000 lb. of magnesia-base liquor solids a day at a daily production of 200 metric of bleached "Magnefite" pulp. Designed for a pressure of 950 p.s.c., the recovery boiler will generate 101,500 lb. of steam per hour at a pressure of 882 p.s.i. and 842° F. at the superheater outlet.

Farrel-Birmingham Co., Inc.

CALENDER ROLL BULLETIN

Available from Farrel-Birmingham Co., Ansonia, Conn., is an unusually informative, well-illustrated 32-page bulletin (123) on calender rolls. Contents include information on selection and maintenance of these rolls. A chapter on "The Complexities of Design" deals with the various aspects of roll design as affected by the individual application and discusses thoroughly such subjects as type of material, temperature control, procedure for determining roll crown, etc. A section devoted to "Roll Manufacture" gives concise description of casting, machining, grinding and testing operations. Suggestions on "Care and Maintenance" include valuable tips on handling and storage, calender operation and lubrication; listed and analyzed are causes and suggested remedies for various types of roll failure—pitting, spalling, denting, scoring, etc.

Bailey Meter Co.

Ralph K. Johnson, application engineer in the proposition department, Bailey Meter Co., has been transferred to the company's Pulp & Paper Division, and will operate from the company's office in East Orange, N. J. Mr. Johnson will specialize in the application of Bailey products and systems serving the pulp and paper industry in Bailey's Region I (eastern) area.

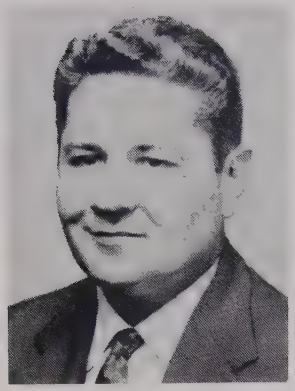
Bailey Meter, whose headquarters are in Cleveland, Ohio, manufactures industrial instruments and automatic controls for the power and process industries.

Beloit Iron Works

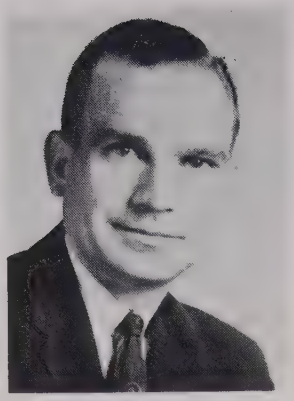
H. C. Moore, president, Beloit Iron Works, Beloit, Wis., recently announced the appointment of Donald R. Simonds as vice-president and general manager of Integrated Projects. This new division is aimed at offering complete equipment for paper mills in the United States and the world market. The Integrated Projects group will be working closely with consulting engineering firms, but the service offered by this

Ralph K. Johnson, Bailey Meter Co.

Donald R. Simonds, Beloit Iron Works



Bernard J. Koziol, Black-Clawson International, Ltd.



David Miller, Corn Products Sales Co.

group is not to be confused with services offered by consulting engineers.

Black-Clawson Co.

Black-Clawson International

The Black-Clawson Co. announces that Bernard J. Koziol has taken up an assignment with the company's Black-Clawson International, Ltd. Div. as manager of paper machine sales. He will make his headquarters in the general offices of BCI in London, England.

Borden Chemical Co.

Availability of a new report which describes 11 adhesives specifically designed for tube winding operations has been announced by The Borden Chemical Co., 350 Madison Ave., New York, N. Y.

The report, number GL-2, offers complete technical data on dextrine, casein, and vinyl resin adhesives. Also included is a discussion of common operating difficulties with recommended solutions, an analysis of adhesive behavior under the influence of machine agitation, and other information such as dilution proportions and mixing instructions. Technical data on each adhesive material are reviewed in terms of its special properties, solids content, viscosity, pH, weight per gallon, color, and storage life. Borden Chemical's tube winding adhesives are available in both compounded and raw material forms.

Clinton Corn drocessing Co.

Appointment of W. Andy King as Clinton sales representative in the South Carolina area has been announced by C. F. Cline, Jr., southern division sales manager, Clinton Corn Processing Co., Greenville, S. C.

Corn Products Sales Co.

David Miller has been appointed industrial sales representative for the upstate New York area by the Industrial Division, Corn Products Sales Co., manufacturers of starches, syrups, dextrose and corn-derived chemicals.

Gaylord Associates

Norman G. Gaylord becomes independent polymer consultant and organizes Gaylord Associates, Inc., New Providence, N. J., to carry out contract laboratory research in the organic and polymer fields. He was formerly vice-president, Research and Development, Polymer Division, The Western Petrochemical Corp.

General Aniline & Film Corp.

The Chemical Group, General Aniline & Film Corp., New York, announces the relocation of its Chicago Branch Office to 1950 N. Hawthorne Ave., Melrose Park, Ill., effective April 15, 1961. The branch was previously situated at 310 W. Polk St. in downtown Chicago.

General Electric Co.

Industrial Marketing Organization

The General Electric Co. has announced a realignment of its industrial marketing organization in the Schenectady, N. Y., headquarters with the establishment of six new managerial posts.

In an announcement by George W. Knapp, manager of the Industrial Sales Operation's new System Sales and Engineering Operation, the following positions have been established and managers appointed within that operation: David A. Yates, manager of systems procedures and practices; Charles B. Elledge, manager of industrial sales and engineering; George R. Brown, manager of metal rolling industry sales; William E. Miller, manager of metal rolling application engineering; L. Frank Lewis, manager of advance planning and projects; F. Morley Roberts, manager of application engineering development.

Education Citation

The American Vocational Association cited General Electric Co. for its national contributions to education and in 32 states where it has industrial plants.

An association spokesman said the award "recognizes G.E. for its many and diverse educational programs serving youths and adults." The association also said G.E. is especially effective with educational activities at the local and state levels where it has industrial plants and facilities.

Speed Measurement Systems

General Electric Bulletin GEZ-3251, 12 pages, describes G.E.'s complete line of a.c. and d.c. tachometer generators and indicators. Bulletin relates information on instruments' applications, calibration, accuracy, and method of selection. Specifications, schematics, and photos of the measurement systems described are also included.

Automation Systems

A new management-oriented publication (GEA-7130) discussing material handling automation systems is now available from the General Electric Co., Schenectady 5, N. Y. It will be of interest to all who are are concerned with cost reductions in the handling of incoming materials, work in progress or finished goods distribution, company engineers report. The eight-page brochure defines the General Electric concept of automated material control (AMC) and lists the benefits to be obtained from such systems. The close tie between material handling automation and related data processing functions is illustrated.

Goulds Pumps, Inc.

New Bulletin No. 722.4 gives complete information on high pressure multi-stage centrifugal pumps manufactured by Goulds Pumps, Inc., 223 Black Brook Rd., Seneca Falls, N. Y. Models 3360–3365 described, have capacities up to 2600 g.p.m. for heads up to 3400 ft. Maximum working pressure 1200 p.s.i. Complete specifications, performance curves, materials of construction, dimensions are among other data given.

Hagan Chemicals & Controls, Inc.

A new brochure describing the operation and application of the Hagan Chemonitor, an instrument that conducts continuous on-stream analyses of critical constituents in water, is now available from Hagan Chemicals & Controls, Inc., Hagan Center, Pittsburgh 30, Pa.

Any colorimetric determination made in the laboratory can be made continuously with the Chemonitor. The brochure describes typical applications such as silica determination on

demineralizer effluents in the zero to 300 parts per billion range. In this low range, the Chemonitor detects silica concentrations as low as 5 p.p.b. with ±2 p.p.b. accuracy.

Hercules Powder Co.

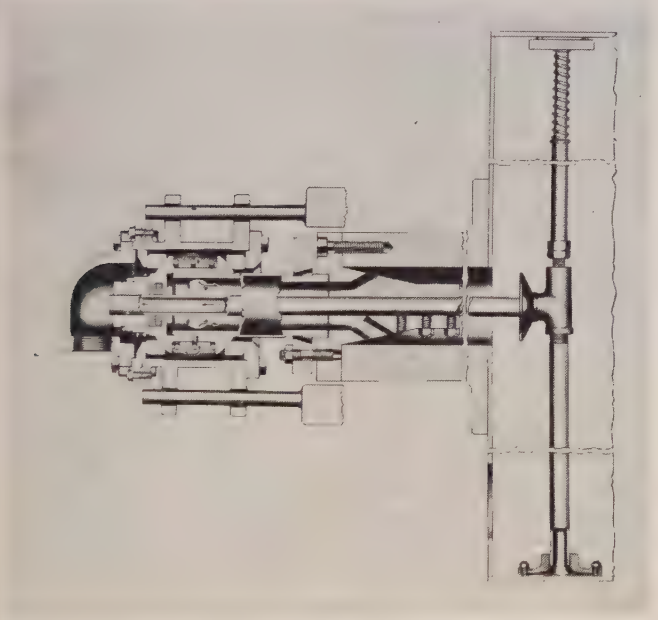
IMPERIAL COLOR CHEMICAL & PAPER DEPT.

Alfred E. Van Wirt has been appointed manager of Hercules Powder Co.'s Imperial Color Chemical & Paper Department. The appointment is effective immediately. A native of Glens Falls, N. Y., Mr. Van Wirt has almost 38 years of experience in all phases of the department's operation. He succeeds Arthur F. Brown, who retired on April 1, to the post.

Johnson Corp.

In announcing a new rotary syphon for drier rolls of paper machines the Johnson Corp. claims an important breakthrough in condensate drainage. Development of this new Johnson rotary syphon had a threefold objective: to achieve maximum temperature along the face of the roll; reduce horsepower demand; and cut maintenance generally. It can be installed on new or existing paper machines, with either open or enclosed gearing.

To evacuate condensate from drier rolls more effectively, the Johnson rotary syphon employs a new concept of pick-up design. This holds the film of condensate to a minimum,



Johnson rotary pressure joint and the new Johnson rotary syphon—a combination that introduces important heat and power gains in draining condensate from drier rolls of paper machines

permitting a more efficient transfer of heat units from the steam to the drier shell. Pick-up fitting can be located at any point along the shell, to keep temperatures more uniform along the face.

Ease of installation is a welcome feature of the new syphon. There is no need to get inside the roll—no internal drilling or tapping. The pick-up fitting is inserted right through the manhole. For drier rolls with handholes only there is even an alternate version which can be inserted through the journal.

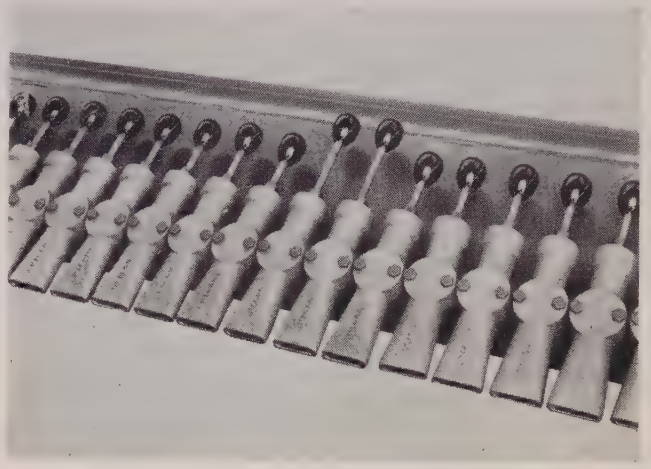
This new rotary syphon is a logical sequel to the Johnson rotary pressure joint, and is engineered for installation with it. The rotary joint is concerned with getting steam into the roll and providing passage out for the condensate. The rotary syphon takes over inside the roll, extracting maximum drying effect out of the heat units contained in the steam.

The full story of the new Johnson rotary syphon—the research and the engineering data behind it—are available in a booklet published by the manufacturer. Paper machine manufacturers and paper mill men who are interested are invited to write for a copy of "Condensate Behavior in Paper Machines" to the Johnson Corp., Three Rivers, Mich.

Lodding Engineering Corp.

SHEET CALIPER CONTROL DOCTORS

A new development to control the caliper of the sheet on paper machine calender rolls has been perfected by Lodding Engineering Corp., Auburn, Mass., the nation's foremost manufacturer specializing in machine roll doctors and allied equipment.



Section of the Lodding sheet caliper control doctor illustrating how the series of valves are regulated independently to direct controlled amounts of air anywhere on the roll

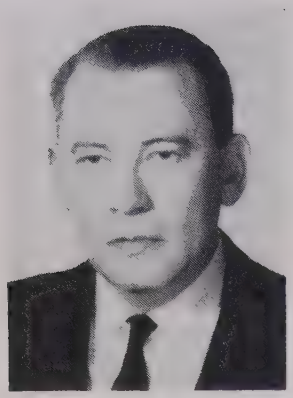
The sheet caliper control doctor operates on the principle of directing controlled amounts of chilled air to any section or sections of the calender roll through a series of independently regulated valves that are positioned adjacent to one another across the full width of the roll. The caliper of any part of the sheet is controlled by opening the necessary valve or valves. This directs chilled air to the desired portion of the roll which shrinks it slightly, thereby increasing the caliper of the sheet at that point. In this manner, by simply regulating the valve openings, precise control over the sheet caliper is maintained.

The valves are mounted along the face of the sheet caliper control doctor at intervals of 2 in. When a valve is opened, air is blown through an aluminum nozzle at a design velocity of approximately 12,000 f.p.m. The high air velocity produced by this nozzle, together with the narrow air stream, results in efficient cooling of the correct spot on the roll. Each nozzle will consume approximately 39 c.f.m. of air at this design velocity.

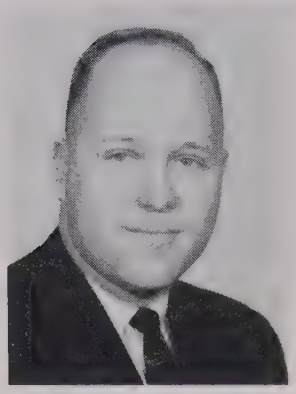
The air supply may be cooled artificially from water coils or mechanical refrigeration units or may be drawn from cooler basement areas. The usual air operating temperature is 60°, however, it should be remembered that greatest efficiency is obtained with the greatest temperature difference between the air and roll.

LATIN AMERICAN AGENT

George E. Soyka has been appointed exclusive sales agent for Mexico and Latin America by Lodding Engineering Corp., Auburn, Mass., world's largest manufacturer specializing in paper machine roll doctors, showers, and associated products. Soyka will handle sales of Lodding products through the firm



George E. Soyka, Castillo Y Soyka



William J. Delaney, Metalsalts, Corp.

of Castillo Y Soyka, located at Isabel La Catolica 45, Mexico (1) D.F., Mexico.

Manchester Machine Co.

The Manchester Machine Co. announced today that they have appointed U. S. Machinery Co. as their export agent. U. S. Machinery will represent Manchester in the sale of paper machines and machine room components to foreign owned and operated paper mills. Manchester will, however, continue to handle all sales to foreign mills owned and operated by American and Canadian firms.

Manchester manufacturers complete paper machines and all machine room components including headboxes, fourdriner and cylinder machines, presses and press sections, driers, calenders, reels, and winders.

U. S. Machinery maintains headquarters in New York City and sales offices throughout Europe, South and Central America, and Japan.

Metalsalts Corp.

As recently announced by A. L. Goeschel, president of Metalsalts Corp., Hawthorne, N. J., William J. Delaney has been appointed product manager for all Metasol Chemicals distributed to the paper industry. The Metasol Division of Metalsalts Corp. manufactures an extensive line of bactericide and fungicides for the paint, paper, textile, and other industries.

Minneapolis-Honeywell Regulator Co.

FLOWMETER HANDBOOK

A new edition of its Flow Meter Engineering Handbook, a recognized reference work for a quarter of a century, has just been published by Brown Instruments Div. of Minneapolis-Honeywell Regulator Co.

First issued in 1936, and revised in 1946, the basic flow calculations rearranged for easy reference and expanded to include primary measuring devices other than orifice plates. The 170-page book, which includes numerous schematic diagrams, graphs, charts, tables and other data, contains separate chapters on stem, liquid and gas flow calculations, each with all data necessary to calculate or check an orifice plate installation. Nomenclature used in the handbook is that approved by major instrument manufacturers and, where applicable, agrees with A.S.M.E. an A.G.A. fluid meter reports.

Price of the book is $7.50. It may be ordered from: Brown Instruments Div., Mail Station 0280, Minneapolis-Honeywell Regulator Co., Wayne & Windrim Ave., Philadelphia 44, Pa.

Monsanto Chemical Co.

Two promotions in the marketing department of Monsanto Chemical Co.'s Plastics Division here were announced by R. C. Evans, director of marketing. Chester L. Jones, director of sales, resin products, has been promoted to assistant director of marketing. Edmond S. Bauer, product administrator, resins and coatings, has been promoted to replace Jones as director of sales, resin products.

Nalco Chemical Co.

FUEL OIL TREATMENTS

An effective, new residual fuel oil treatment designed to minimize slag and corrosion in boiler systems is described in product bulletin El-159, available from Nalco Chemical Co., 6216 W. 66th Place, Chicago 38, Ill.

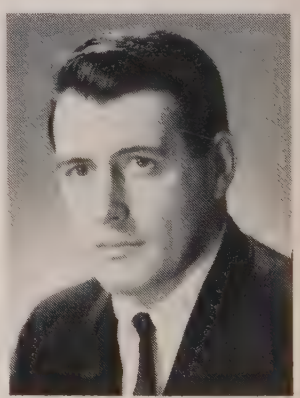
COLLOIDAL SILICA

A new, acidic, high-purity colloidal dispersion of silica, Nalcoag 1034A, is now being marketed by Nalco Chemical Co., Chicago. The salt-free silica sol is miscible with a number of organic solvents and has a pH range of 2.6 to 3.6. Utilized to improve nonskid characteristics of bags and boxes, to increase fiber-to-fiber friction in textiles, to increase bonding strength of cements, to form protective film on metals, and for a variety of other uses—it can be applied by spray, roller, dipping, wiping, or brush.

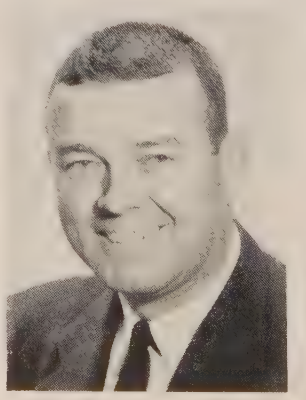
STAFF

Promotions of R. E. Eddy, Orell Collins, and P. M. Henry to Industrial Division District Managers, have been announced by Nalco Chemical Co., Chicago based manufacturer of water conditioning, petroleum treating, and other industrial chemicals.

Mr. Henry moves to his new post as manager of the company's Mid-South District from the Pacific Northwest, where he was a district representative. Mr. Eddy, formerly Product Manager of Nalco's Papermaking Chemicals Department in Chicago, takes over the Southeastern District with headquarters in Jacksonville, Fla.; Mr. Collins, who was Area Manager in Nalco's Texas District, heads a newly created South Atlantic District, with offices in Charlotte, N. C. The South Atlantic District was portioned from a larger Southeastern District, previously under the managership of T. G. Cocks, who recently moved to Chicago as vice-president of Nalco.



R. E. Eddy, Nalco Chemical Co.



Orell Collins, Nalco Chemical Co.

P. M. Henry, Nalco Chemical Co.

National Starch and Chemical Corp.

Joseph D. Russo has been named supervisor of National Adhesive's Technical Development Laboratory at San Francisco. He will assume responsibility for the operation of the adhesive technical development and service functions of the West Coast Division of the company.

Ohmart Corp.

NUCLEAR DENSITY GAGING LITERATURE

Two new two-page specification sheets (ASR-3 and LASR-3) describe features and technical characteristics of nuclear density measuring gages for processing applications employing pipe 3 in. in diameter or smaller. Copies are available from The Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.

LABORATORY AND PILOT PLANT NUCLEAR THICKNESS GAGE

A new small size nuclear thickness gage, using beta radiation, has been developed by The Ohmart Corp., Cincinnati, for applications in industrial research laboratories and pilot plant operations. Measuring only 22 in. long, the new measuring instrument will accurately indicate or record the thicknesses of sheet materials up to 12 in. wide. The new gage should be extremely useful in the laboratory determination of thickness or density of plastic films, paper, coated materials, rubber, glass, floor coverings, and metal foils.

Parsons & Whittemore-Lyddon Organization

Nicholas Shoumatoff has joined the Parsons & Whittemore-Lyddon Organization as an executive engineer in the Pulp & Paper Mill Project Div., Lyddon Co. Ltd., London, England. As chief engineer, he will supervise the contract engineering, design engineering, and purchasing groups. Mr. Shoumatoff assumed his duties in London on April 1 under W. O. Hisey, director of Lyddon, who is in charge of the planning and engineering of all mill projects assigned to the London office of the organization.

Nicholas Shoumatoff Lyddon Co., Ltd.

Pfaudler Permutit, Inc.

A four-page bulletin (1007) describing Pfaudlon 301, a medium priced, corrosion resistant plastic coating for metal, is now available from The Pfaudler Co., a division of Pfaudler Permutit, Inc., Rochester, N. Y., specialists in corrosioneering and fluid handling equipment. According to the bulletin, Pfaudlon 301 which is a sprayable coating of Hercules Penton in water solution, has many areas of application in the process industries. It can be used as an exterior coating to protect against acid spillage or corrosive ambient atmosphere; or an interior product contact coating for protection against corrosive attack by most acids, alkalies and salts plus many solvents to 210°F. The new bulletin tabulates recommended service and typical equipment applications as well as base metals to which Pfaudlon 301 has been successfully applied. A complete list of physical characteristics is also included.

Reliance Electric & Engineering Co.

DUTY MASTER MOTORS

Full color Bulletin B-2515 issued by the Reliance Electric and Engineering Co., Cleveland 17, Ohio shows and describes the complete line of new Reliance Duty Master a.c. motors from 1 to 2000 hp. Product features of each motor are clearly outlined and explained for easy selection of the right motor for every application.

AIRTROL BULLETIN

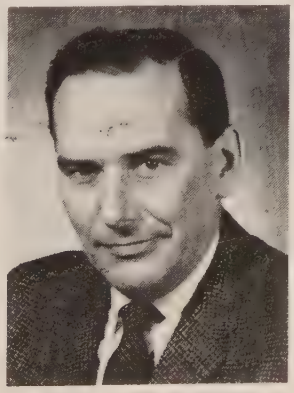
The new Reeves AIRtrol Bulletin (G-2500) explains how drive speeds of machines and processes can be automatically controlled and regulated by simple pneumatic instrumentation. Concise drawings and descriptions show how AIRtrol can be applied to control liquid level, line pressure, process temperature, constant flow, steam pressure and motor loading. Web processes such as dancer roll tension and center-wind tension may also be controlled. A number of pneumatic pressure control systems are possible including manual remote, automatic open loop, automatic closed loop, and multi unit systems.

Rice Barton Corp.

The appointment of Philip A. Peterson as chief engineer in charge of trailing blade coater ranges of Rice Barton Corp., Worcester, Mass. is announced by Charles S. Barton, president, and Frederick T. Coker, executive vice-president. Mr. Barton stated that use of trailing blade coaters has expanded to the point of requiring a separate department. Mr. Peterson is a specialist in coating methods and equipment and will be responsible for both engineering and sales. Prior to this appointment Mr. Peterson has been a sales engineer. He joined Rice Barton in 1951 after 4 years with Oxford Paper Co.

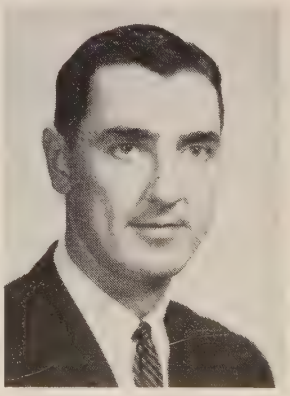
W. Lewis Ayers was appointed sales engineer. This is a further move in Rice Barton's program to provide better service for paper mills made necessary by more activity in the northeast. Mr. Ayers will cover Maine, New Hampshire, and Vermont from the Worcester sales office. Prior to this appointment Mr. Ayers has served in the engineering, estimating, and internal sales departments. He joined Rice Barton in 1948.

Philip A. Peterson, Rice Barton Corp.



W. Lewis Ayers, Rice Barton Corp.

W. Ernest Stone, Rice Barton Corp.



Lelano L. Boutin, Rice Barton Corp.

W. Ernest Stone was named to the new position of manager of field service. Mr. Stone will supervise all machinery erection and customer installations and will coordinate all activities between the field service and the Worcester plant. Mr. Stone has been with Rice Barton for 23 years as sales manager and sales engineer.

Delano L. Boutin, sales engineer for Rice Barton Corp., has been assigned to the Savannah, Ga., sales office.

J. O. Ross Engineering

The Ross Hooper hood has undergone a design change, according to R. W. Grott, chief engineer, Paper Mill Dept., at J. O. Ross Engineering, division of Midland-Ross Corp. The hood, a familiar piece of equipment on the dryer section of most modern paper mills, will have a new shape and new construction.

Some of the features of the new hood include aluminum-clad panels that have added insulation, allowing for the operation of the hood at higher drybulb and dewpoint temperatures. This will also improve the quality of the paper, as well as reduce the radiation to the machine room. The top hood panels have 3 in. of insulation, and the front lifting and rear sliding panels have 2 in. The new shape of the hood, along with an internal revision, allows for the withdrawal of air symmetrically from the front and rear of the paper machine. This improves the air flow through the hood and considerably simplifies both construction and installation.

Continuous windows will be a standard part of the new Ross Hooper hood. The windows will run the entire length of the front side of the machine for increased "viewability."

Another feature of the new hood is the elimination of the front corner posts. This means that when the lifting curtains are raised, the operating aisle is completely free, giving even greater access to the machine.

Shawinigan Resins Corp.

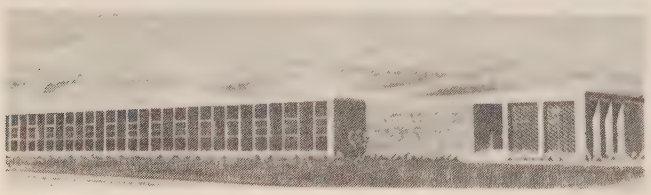
Three executive appointments in Shawinigan Resins Corp.'s research department and the elevation of five persons to research section leader posts have been announced. Effective immediately, Edward Lavin is director of applications research; Aubrey F. Price is director of product research; and Harold D. Weymount is director of research administration and planning. Those appointed to section leader include: Dr. Albert H. Markhart, Leo J. Monaghan, Dr. Ralph F. Nickerson, Dr. Forrest H. Norris, and Herbert Terry. The appointments are effective immediately.

Southern Clays, Inc.

Southern Clays, Inc., of New York City, announces the opening of a new research laboratory and pilot plant with the most modern facilities and equipment available.

The new laboratory and (separate) pilot plant are located on the shore of a 24-acre lake on a 90-acre wooded site, near Gordon, Ga., about 1 mile from the main plant.

The laboratory is some 16,000 sq. ft. in size and is subdivided into five main groupings: functional research, ceramics, paper, new product development, and organic applications—primarily paint, rubber, and plastics, with associated service areas such as instrument rooms, darkroom, constant humidity room, library, conference, reception and offices. The pilot plant, containing some 6000 sq. ft., is in a separate building approximately 200 ft. from the lab.



New research laboratory, Southern Clays, Inc.

A. E. Staley Mfg. Co.

Paul E. DiBenedetti, A. E. Staley Mfg. Co.

Paul E. DiBenedetti has been promoted to market development representative in the paper section of the A. E. Staley Manufacturing Co.'s market development division. Mr. DiBenedetti has been in commercial development work with the U B S Chemical Co. in Cambridge, Mass., a division of Staley's. In his new position, he will serve the paper industry in the Eastern United States and introduce new products for the industry from Staley's.

Stauffer Chemical Co.

A comprehensive 40-page booklet on the properties and uses of aluminum sulfate has just been published by Stauffer Chemical Co. Essentially a reference handbook, the publication includes data on the manufacture of alum, grades available, principal uses, and methods of handling. A major feature of the new booklet is a series of convenient conversion charts and tables, e.g. gravity and weight equivalents of solutions, solubility, alum feed rates, gravity and temperature relationships, viscosity determinations, and analytical procedures. Also included are standards and specifications for alum for water and sewage treatment of the Federal Agencies and of the American Water Works Association.

Copies of the handbook are available without charge from Stauffer Chemical Co., 380 Madison Ave., New York, N. Y.

Stickle Steam Specialties Co.

A new wet end drier control system for use in the production of all types of paper and board is offered by Stickle Steam Specialties Co., 2215 Valley Ave., Indianapolis 18, Ind.

Designed to improve the finish and prevent picking, curling, and cockling, it is said to be the fastest acting, simplest and most accurate system of its kind. The system automatically maintains any temperature desired in each drier at the wet end where accurate temperature control is essential. The system has a control station for each drier and shows at a glance the temperature set, actual temperature inside the drier, and flow and temperature of condensate leaving the drier.

Sun Chemical Corp.

A new air-drying solvent solution that substantially increases the resistance of paper and paperboard products to water and weathering has been developed by the Paper Chemicals Dept. of Warwick Chemical Div. of Sun Chemical Corp., Wood River Junction, R. I.

Designated Impregnole 367, the new material is a mixture of General Electric silicone polymers and other film-forming ingredients. It has already been used with great success by automobile assembly plants in treating boxes for outdoor storage of spare parts. In this instance, Impregnole 367 was applied to finished boxes. The material can also be applied to sheet stock with equal success.

Impregnole 367 is designed to be used diluted in solvent to approximately 5 to 10% solids and may be applied by spraying or swabbing, followed by air drying. Its properties include: flash point or more than 80°F.; 50% solids; and it is noncorrosive.

Taylor Instrument Cos.

Taylor Instrument Cos., Rochester, N. Y., has announced

a new, moderately priced, direct-reading relative humidity recorder. Identified as the 100J Series, the instrument is available in four models, providing for such features as hand portability or wall mounting, and for recording of the dry-bulb temperature on the same chart with the relative humidity.

Testing Machines, Inc.

Testing Machines, Inc., 72 Jericho Tpke., Mineola, N. Y., now makes available two design and manufacturing services. Under this plan: (1) testing machines can be custom designed and built to suit a particular testing requirement, and (2) your own design for a testing machine or instrument can be produced or sold commercially. TMI can work from a basic sketch and follow the matter to the ultimate stages of manufacture and distribution.

Listing of Testing Machines

Technical and purchasing executives may now obtain a new 20-page selected listing of testing machines for all industries. It has 69 categories of physical testing such as abrasion, hardness, moisture, impact, tensile, and 64 additional categories. A total of 461 testing machines is covered. The equipment has been compiled from world-wide sources, including units manufactured by Testing Machines, Inc. and many other prominent instrument and testing machines manufacturers. Price information is included on all of the instruments listed.

Union Box Measuring Gage

The Union box measuring gage solves a problem which, offhand, seems simple but which has plagued the packaging industry for years. Many times a customer will find that his product will not easily or properly fit in a box which is slightly undersized or it might fit too easily in a box which is oversized. The Union box measuring gage is a big step toward standardization of measurement and can help box manufacturers and users alike. It has a telescoping rod and a tube of $^1/_2$ in. i.d. square cross section fitted at each end with a flat 4 by 3-in. plate. The rod is marked with a scale reading in inches and the tube is fitted with a pin locking device which automatically locks the rod at even increments of 1 in. as it is withdrawn from the tube. A small "window" in the tube shows the inch setting at which the rod is locked. The set of three gages covers any inside box dimension from 6 to 34 in. Measurement is obtained simply by telescoping the rod to the largest inch mark which will permit insertion of the instrument into the box. The exact inside dimension is then read directly from the instrument by adding the number dimension shown in the small "window" to the fractional part of an inch shown on a vernier.

Tomlon Corp.

Tomlon Corp., 199 Jackson St., Trenton 10, N. J., announces availability of an entirely new, simplified, hydraulically operated actuator for doctor knives, showers, felt conditioners and similar equipment where a positive, controlled, oscillating motion is required. An automatic safety overload is included.

Hank D. Jones and Associates was appointed as a paper industry sales representative for the new Tomlon hydraulic oscillator. Mr. Jones and his associates will represent Tomlon Corp. in the Southern Territory which includes the States of Virginia, North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana, Tennessee, Texas, Oklahoma, and Arkansas.

Also, the Ray Smythe Co. of Portland, Ore., has been appointed Western Sales Representative for the Paper industry. Their territory includes the States of California, Oregon, Washington, Idaho, and Montana and the Province of British Columbia.

U. S. Stoneware Co.

A new fluoro-elastomer (Fluran F-5000) with maximum operating temperatures ranging from 400°F. in continuous service to 600°F. in intermittent use, a low temperature brittle point near −40°F. and a broad range of resistance to corrosive chemicals, fuels, and lubricants is now available in tubing, hose, and press polished sheets from The U. S. Stoneware Co., Akron 9, Ohio. Die cut and clicked gaskets to individual specifications can also be supplied.

Virginia Chemicals & Smelting Co.

A. K. Scribner, company president, made the following announcement: "In order to reflect more accurately the nature of our business, we have changed our name from Virginia Smelting Co. to Virginia Chemicals & Smelting Co." The company is actively engaged in the manufacture and sale of chemicals, refrigeration products, and aerosols which are being marketed both domestically and overseas.

Wallace & Tiernan, Inc.

Wallace & Tiernan, Inc., Belleville, N. J., announces an improved version of the variable area flowmeter for fluid metering. It will be marketed under the trademark of "Varea-meter" in glass-tube and metal-tube models. Glass-tube capacities with standard floats are 0.25 to 310 g.p.m. of water, or 1.1 to 1300 s.c.f.m. of air, against up to 350 p.s.i.g. and 400°F. Tube diameters range from $^3/_8$ to 3 in., with scale lengths of 5 or 10 in. Tubes and corresponding floats are available in two types: a plain tube with a rod-guided float, or a tube with beads to guide the float. All critical dimensions conform to I.S.A. Recommended Practice.

General

Automatic Control Conference

Recent advances in automatic control will be discussed at the Second Joint Automatic Control Conference, June 28–30, 1961, at the University of Colorado, Boulder, Colo. To assure comprehensive coverage of significant progress five leading societies have provided active sponsorship and programing support—AIChE, AIEE, ASME, IRE, and ISA. Attendance of 1000 control engineers and scientists from the United States and Canada is expected to fill the housing facilities at Boulder. Advance registration and reservation forms for housing and social functions are available from the Meetings Manager, ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

Eucalyptus Conference

The most widely planted tree species in the world, in terms of plantation area, will be studied at the Food and Agriculture Organization's Second World Eucalyptus Conference, to be held in Saõ Paulo, Brazil; from Aug. 13–26, 1961. Expanding use of eucalyptus is due to its remarkable adaptability to various climates and soils.

The conference will provide a forum for the progress achieved in research on basic problems, silviculture, influences, utilization and socio-economic value of eucalyptus plantations since the First World Eucalyptus Conference held in Rome in 1956. It will also provide an opportunity for strengthening world-wide cooperation in research, and for discussing the establishment of a "Certified Eucalyptus Seed Collection Centre and Clearing House Service," which was requested by FAO's Asia-Pacific Forestry Commission and Mediterranean Forestry Sub-Commission.

International Corrugated Case Association

Jerome H. Stone, executive vice-president, Stone Container Corp., Chicago, and president of the Fiber Box Association, has been elected president of the newly formed International

Corrugated Case Association at that group's organizational meeting in Paris, France, on March 17, 1961.

Representatives of corrugated box associations from 19 nations whose members produce approximately 80% of the world production of corrugated shipping cases were present at the meeting. Other elected officers of the new Association were Dr. W. F. Klingele, president, Federation Europeenne des Fabricants de Carton Ondule (FEFCO), Heidelberg, Germany, as vice-president; R. du Boucheron, secretary delegate general, FEFCO, Paris, France, as executive secretary for Europe; and Albert W. Luhrs, executive manager, Fiber Box Association, Chicago, Ill., as executive secretary for other nations.

The new association will sponsor the interchange of information among corrugated manufacturers in all nations. This material will include new developments in shipping containers, comparison and study of common carrier packaging regulations, uniform nomenclature, and other subjects for the progress and improvement of the corrugated box industry throughout the world.

The next meeting of the International Corrugated Case Association will be held in New York City in the Fall of 1961.

Inter-Society Color Council

GODLOVE AWARD

For outstanding contributions to the knowledge of color in science, art, and industry, Miss Dorothy Nickerson, color technologist, cotton division, agricultural marketing service, United States Department of Agriculture, was named as the third recipient of the Godlove Award of the Inter-Society Color Council. The award was presented by G. L. Erikson, president of the Inter-Society Color Council, at a banquet held during the 30th annual meeting of the council in Rochester, N. Y., at the Sheraton Hotel.

Ontario Research Foundation

In preparation for a "forthcoming boom" in Canada's industrial and technological development, Ontario Research Foundation, 43 Queen's Park, Toronto, is embarking on a long-range plan for expansion and growth.

A. Donald Misener, director, has announced that ORF will begin immediately to put into effect the following steps designed to make the 32-year-old research organization increasingly effective in serving the needs of industry and government:

1. An expansion of its scope of research services to include a greater proportion of research contracts from U. S. and European companies.
2. A concomitant enlargement of research staff.
3. A broadening of fields of scientific endeavor to include newer technologies and technical specializations and make available a more complete research service for clients.
4. A physical expansion program, which contemplates the purchase of new equipment, enlargement of present facilities, and eventually the relocation of the Foundation in a new "research community" in the Toronto-Hamilton area.

Ontario Research Foundation was created by an act of the Ontario Legislature in 1928 to provide facilities for scientific research. Its endowment was provided jointly by industry and government, which it serves in a wide variety of research and technical advisory capacities. It has 179 staff members, including some of the most distinguished of Canadian scientists.

Manufacturing Chemists' Association

Revised editions of four chemical safety data sheets are now available from the Manufacturing Chemists' Association, Inc. These booklets on benzene, SD-2; nitric acid, SD-5; paraformaldehyde, SD-6; and anhydrous ammonia SD-8 list not only the characteristics of these chemicals, but also the hazards, engineering control of hazards, employee safety procedures, fire fighting techniques necessary, recommended handling and storage practices, tank and equipment cleaning and repair procedures, waste disposal, medical measures necessary, and first aid requirements.

Measurement of Visual Impact

Scientific measurement of the visual impact of packages, products, and advertisements is now practical through a electronic device called the Visiometric Comparator. This machine accurately evaluates legibility and makes possible the establishment of standards for visual efficiency invaluable to the product manufacturer, package designer, and advertising manager. It is produced by the R. E. Van Rosen Div. of The Technopak Corp., New York.

The device has been under development for several years and is based on the principle of light affecting the transparency of materials. A specially treated screen is positioned between the items being evaluated and the observer. Banks of incandescent tubular lamps in front of and behind the screen are controlled by an electronic unit so that brightness is increased or diminished. The result is a gradual increase in the transparency of the screen which can be measured very accurately by a voltmeter. Readings taken on segments of the package or advertisement are scored, and the average of all measurements taken is the legibility quotient of the item measured.

The machine also incorporates a tachistoscope, a unit measuring what is seen in a flash view of an object. It measures the ease and speed of recognition of design elements within the range of 50 millisec. to 10 sec.

National Safe Transit Committee, Inc.

National Safe Transit Committee, Inc., 1145 19th St., N. W., Washington 6, D. C., announces a technical consultation and verification service designed to provide strong technical re-enforcement to its already nationally recognized preshipment testing program. Under its new plan, NSTC, Inc. will furnish the services of field technical consultants to certified testing facilities. All NSCT certified testing laboratories will be visited on a schedule basis in order to assist each facility to verify and maintain its qualifications and performance standards under the NSTC program. Concurrent objectives will be to confirm proper use of procedures and Safe Transit labels.

Waxed Paper Institute, Inc.

Harold E. Pierce, sales manager of bakery packaging Marathon, a Division of American Can Co., Menasha, Wis., was elected chairman of the Waxed Paper Institute, Inc. for 1961 at the Institute's annual meeting. Mr. Pierce succeeds Robert M. Koch, vice-president and general manager, Zimmer Paper Products, Inc., Indianapolis, Ind., who served as chairman of the Institute during 1960.

The Institute Board of Directors elected Lloyd L. Fisher, manager, bakery packaging, Western-Waxide Div., Crown Zellerbach Corp., San Leandro, Calif., to the office of vice-chairman for 1961. This position was formerly filled by Mr. Pierce.

Edward A. Greer, vice-president, sales, The Specialty Papers Co., Dayton, Ohio, was chosen to succeed Mr. Fisher as secretary-treasurer of the Institute for 1961.

Mr. Pierce, Mr. Fisher, and Mr. Greer, the newly elected officers, make up the administrative committee. In addition, Mr. Greer heads the Institute's finance committee for 1961.

OBITUARIES

Sverre Hall Grimnes

Sverre (Steven) H. Grimnes, consulting engineer died suddenly of a heart attack on April 10, 1961 at Ann Arbor, Mich.

Mr. Grimnes was born in Bergen, Norway, on August 27, 1898 and graduated as a mechanical engineer from the Technical University of Norway in 1922.

He came to the United States in 1927 as a design engineer for General Motors Research Division. From 1937–1945 he was plant engineer for the Munising Paper Co. In 1946–47 he was an engineer with U. S. Wallboard Machinery Co. and in 1947 he became chief engineer for the BFD Division of Diamond Match Co. In 1956 he became a project engineer for Ebasco Services, Inc. and since 1958 he was associated with Cassell Associates and Cummings & Barnard, consulting engineers in Ann Arbor, Mich. He was registered as a professional engineer in Michigan and was active in the Engineering Division of the Technical Association of the Pulp and Paper Industry.

Richard Hendrick Laftman

Richard H. Laftman, retired former vice-president of National Container Corp. and past vice-president of the Technical Association of the Pulp and Paper Industry, died in Jacksonville, Fla., on March 28, 1961, following a long illness.

Dick Laftman was born in Billingsfors, Sweden, on Sept. 28, 1886, the son of August Laftman, managing director of the Billingsfors-Langed A/B. He graduated as a chemist from Orsbro Technical School in 1909, following which he served an apprenticeship in the pulp mill at Billingsfors.

In 1911 he emigrated to the United States where he joined J. H. Wallace during the design and construction period of the Southern Paper Co. plant at Moss Point, Miss. He remained as superintendent of the pulp department until 1916 when he moved on to the Chesapeake Corp. mill at West Point, Va., as general superintendent.

In 1918 the U. S. War Department called upon him to do experimental work and later to superintend U. S. Government Powder Plant at Nitro, W. Va., which was operated by the Hercules Powder Co. In 1919 he joined the Bogalusa Paper Co. at Bogalusa, La., as pulp mill superintendent; was made general superintendent in 1920; assistant manager in 1923, and vice-president and general manager in 1925.

In 1931 he returned to Sweden as vice-president and general manager of Billingsfors-Langed A/B where he remained until 1935. During 1936 he was employed by "Seangreaseproof," a selling cartel for greaseproof papers.

In 1937 he returned to the United States and was employed by the National Container Corp. as general manager in charge of the construction of the Jacksonville, Fla., mill. He later became vice-president and general manager and in 1946 became a director. During this period the company acquired the Bedford Pulp & Paper Co., Ontonagon Fibre Corp., and Tomahawk Kraft Paper Co.

In recognition for wartime services he was awarded the King Christian X medal of liberation and later the cross of the Order of Dannebrog by the Danish Government. He served as honorary vice-consul of Sweden since 1940 and received the Order of Vasa from the King of Sweden.

He was vice-president of TAPPI in 1930.

He is survived by his wife Mrs. Hedwig Laftman; a daughter, Mrs. Sigrid Sandstrom, and two grandchildren.

Silvain Ginsbourger

Silvain Ginsbourger, publisher of the *Paper and Twine Journal*, died on April 7, 1961.

Mr. Ginsbourger was born in Alsace Lorain on Feb. 4, 1895, and was editor of the *Paper and Twine Journal* for 35 years.

Jack H. Waggoner

Jack H. Waggoner died suddenly at the age of 66 at the University Hospital in Columbus, Ohio, on Feb. 21, 1961. Immediately prior to his death, Mr. Waggoner had been consultant to the Fiber Glass Division of the Pittsburgh Plate Glass Co.

Born Jan. 13, 1895, in St. Joseph, Mo., he was raised in Topeka, Kans. He received the Bachelor of Science degree from the University of Kansas in 1920 after having served during World War I as an Ordnance Sergeant in the United States Army. He also did graduate work at the Massachusetts Institute of Technology.

Mr. Waggoner had extensive experience in the ceramic industry and more particularly in the detail and development of glass manufacturing and its uses.

In 1945, he was made scientific consultant to the United States Army and sent to investigate the glass industry in Western Germany; he received a citation for this service.

Surviving are his widow, the former Marion F. Chutter, 240 Quentin Road North, Newark, Ohio; two sons, Jack H. Waggoner, Jr., Assistant Professor of Physics at the University of California, Riverside, and Chandler C. Waggoner, Administrative Assistant to the Head of the Water Supply and Water Pollution Research Program at the Robert A. Taft Sanitary Engineering Center in Cincinnati, Ohio; a daughter, Mrs. Harvey E. Wahls of Raleigh, N. C.; a grandson; a sister, Mrs. Donald E. Swan of Topeka, Kan.; and a brother, Kenneth G. Waggoner of Alameda, Calif.

William S. Allmond

William S. Allmond, III, Hopewell, Va., died suddenly Thursday, April 10, 1961. Mr. Allmond, a sales engineer for Improved Machinery, Inc., Nashua, N. H., was visiting at the home of his father-in-law in Wilmington, Del. He was 34 years old.

Allen M. Cadigan

Allen M. Cadigan, who retired as chief chemist at the St. Regis, Tacoma, Wash., mill in 1957, died recently.

Mr. Cadigan was born May 27, 1892, in Holyoke, Mass., and graduated from Pennsylvania State College in 1917. During the summers he worked for the New York & Pennsylvania Co., in Johnsonburg, Pa. In addition to N. Y. & Penn., he worked for International Paper Co., Union Bag & Paper Corp., Mattagami Pulp & Paper Co., Grays Harbor Pulp & Paper Co., and St. Regis Paper Co. He was chief chemist at the Tacoma plant of St. Regis from 1944 until his retirement.

A member of TAPPI since 1918, he is survived by his wife, Mae E., two sons, Robert A. of Denver and James E. of Tacoma, and eight grandchildren.

DIVISIONS AND COMMITTEES

Reports of Activities

Authorized Committee Assignments

The following new assignments initiated in committee during the month of April, 1961, constitute the continuing association activities of the committees indicated. These TAPPI assignments are activities that are carried on in addition to the planning of meeting programs. The TAPPI numbers assigned cover the committee work performed in connection with conferences, monographs, standards, data sheets, routine control methods, special reports, conference papers, etc. These numbers are assigned by TAPPI Headquarters.

Assignment no.	*Committee*	*Title and objective*	*Committeeman in charge of assignment*
		COATING AND GRAPHIC ARTS DIVISION	
1009	Graphic Arts	"Monograph." To prepare and publish a monograph relating to the printing processes, and the papers used by printers. To so write and describe the processes, that the mill man or the printer will gain an insight into the requirements and problems of paper and printing processes for specific requirements of products.	M. C. Rogers
1010	Coating	"Suggested Projects for Graduate School Thesis Work." Compile and circulate a list of problems or projects suitable for consideration by universities and colleges as thesis subject at the graduate level. The problem selected should be such as to stimulate interest in paper coating and develop new technical information in this field.	C. C. Kessler
		CORRUGATED CONTAINERS DIVISION	
3003	Steering and Advisory	"Fifteenth Corrugated Containers Conference" 1965 Conference to be held in Atlanta, Ga.	
3004	Steering and Advisory	"Sixteenth Corrugated Containers Conference" 1966 Conference to be held in Los Angeles, Calif.	Not yet delegated
		ENGINEERING DIVISION	
4015	Electrical Engineering	"Equipment Grounding for Safety." To clarify the wide variations in recommended grounding practices for the paper industry. (Revision of C. A. No. 862.)	S. A. Bobe
4016	Corrosion	"Standard Definitions of Corrosion Terms." To develop a standard terminology for describing, discussing, and reporting on the types, causes, and results of corrosion.	H. B. Harris, Jr.
4017	Electrical Engineering	"Use of Static Devices for Over-Current Relays and Trip Devices." Review the status of available static protective devices.	S. A. Bobe
4018	Electrical Engineering	"Developments in Turbo-Generator Excitation Systems." To present new developments and methods in excitation as informative paper.	S. A. Bobe
4019	Electrical Engineering	"Power Factor Considerations in Paper Mills." To review present practices in paper mills to control power factors and consider the economics of the problem.	S. A. Bobe
		PULP MANUFACTURE DIVISION	
6005	Pulp Purification	"1963 Pulp Bleaching Conference"	
		RESEARCH AND DEVELOPMENT DIVISION	
7004	Wood Chemistry	"Isolation of Dimers from Lignin" (project appropriation renewal previous P.A. grants Nos. 116, 165.	
		TESTING DIVISION	
8015	Pulp Testing	"Forming Handsheets for Physical Tests of Pulp T 205 m-58." To prepare more satisfactory specifications for blotting paper used in T 205 m-58.	J. d'A. Clark
8016	Optical Methods and Pulp Testing	"TAPPI Sheet Mold Method for Preparation of Handsheets for Brightness." To provide an improved alternative to T 218 (for eventual replacement).	B. B. Thomas
8017	Chemical Methods	"Carboxyl Contents of Cellulose." To write a test method.	W. K. Wilson

Converting and Consuming Division

Paper-Plastics Committee Project 803 Subcommittee Meeting

The purpose of this subcommittee, which is a task force of the general Plastics Committee of TAPPI is to assemble and arrange in logical order the wealth of technical information necessary to the proper utilization of plastics and paper in combination for decorative and utilitarian purposes. The subcommittee will be guided in its work by a steering committee made up of competent representatives of organizations other than TAPPI having competence and general interest in the area outlined. These organizations will include A.S.T.M., S.P.I., and all such other organizations as have interests in this area. The steering committee's objective is to insure that the catalog is set up in the manner most useful to all groups. It is felt that this work will assist the converters and consumers of packaging material in the utilization and control of such composite materials.

Project 803 Subcommittee meeting during 46th Annual Meeting, February 1961. Chairman: R. W. Loheed, Chas. T. Main, Inc.; acting secretary: K. L. Fischer, U. S. Tariff Commission

The hoped-for order of procedure for the committee's accomplishment of this task may be outlined as follows:

1. Establish a frame of reference within which to work;
2. Catalog within the frame of reference;
3. Make the frame of reference known to interested parties within industry and government;
4. Encourage the parties enumerated in 3 (above) to interject their thinking within the framework of the committee's objectives as stated in the first paragraph.

It is felt that this method of procedure will lead to productive organization, which will snowball into an acceptable catalog.

With regard to establishing a frame of reference within which to work, Mr. Loheed suggested three areas of interest: (1) impregnation, (2) coating, (3) laminating.

It is felt that there is no clear line of demarcation between impregnants and coatings, or board and kraft, etc., and that this committee should establish such lines of demarcation. Later, if a member of industry can justify a desired change, we can adjust for this.

Mr. Altieri asked whether we would include adhesives in the catalog. Mr. Loheed replied that this was not our intent, for if we tried to include adhesives with their many formulations, it would swamp the committee. Mr. Dobbins stated that he feels adhesive raw materials should be listed as basic chemicals (e.g., vinyl acetate, etc.).

Mr. Loheed has been collecting information on resins presently available and attempting to classify them by chemical families. A portion of this information is in the form of data sheets put out by manufacturers, and many "oddball" trade names are used. These names tend to identify the resin with the manufacturer rather than with the family of resins. We should find out what chemical each trade name refers to and classify it according to its chemical family. Mr. Dobbins suggests that TAPPI monograph No. 5, "Resins for the Paper Converter" might be useful in this respect.

Mr. Sweeney expressed the thought that, with regard to surface coatings, the catalog could be set up on the basis of the paper or paperboard used—e.g., kraft paper, paperboard, and specialty papers. These main categories could then be broken down into subcategories such as cup board stock, food grade board, etc.

Using as a starting point the information which Mr. Loheed has already gathered, Mr. Sweeney volunteered to collect further information regarding coating plastics and their combinations with paper, and Mr. Starke volunteered to collect further information regarding impregnating plastics and their combinations with paper. It was stated that Mike Hecht has already contacted some paper manufacturers regarding the paper-plastics combinations which they manufacture.

It is felt that the subcategories "bleached" and "unbleached" should be attached to the main categories—paperboard, kraft papers, and specialty papers; further that we should set specifications with regard to caliper, allowing the endless arguments as to what is "paper" and what is "paperboard" rage on. The categories and subcategories should be kept broad.

There are a limited number of basic plastic families. They can be defined, and the materials which belong in each family tree listed. The combinations can then be catalogued. We can define the basic substrates, and describe the paper-plastics combinations as representative examples, being careful to pick for examples, combinations differing from any being manufactured at present. Ultimately it is envisioned that cross-indexing will be necessary. For instance, this would be useful in the case of a mashed potato package containing foil, polyethylene, and paper.

An initial effort with regard to setting standards should be made by cataloguing standards which already exist, leaving pages blank to be later filled in. The government in conjunction with industry publishes commercial standards which are not binding upon the manufacturers. An example given was the standard on polyethylene unsupported films. The standard could be listed, along with possible combinations of this film with papers and boards. In other words, we should gather available information, catalog it and distribute it to industry to obtain its reaction.*

Mr. Loheed feels that each of the TAPPI Plastics Committee subcommittees should be helpful in its own area of the projected catalog. Mr. Altieri said he will keep the Project 803 Subcommittee informed regarding any work his deinking subcommittee accomplishes relating to our interest. TAPPI has rejected the idea of initiating a research project on deinking and plastics removal from paperstock, but Mr. Altieri says that reconsideration of this decision is possible.

There were no objections voiced to the stated feeling that the project 803 subcommittee should meet twice annually—at the annual TAPPI meeting during part of February in New York City, and at the annual paper-plastics conference, which is held in the early fall of each year at a different location.

Mr. Loheed feels that there is a potential great breakthrough in the province of freeze-drying by sublimation. At present the Army Quartermaster Corps is looking into this subject with regard to paperboards and their combination with plastics, and, there is research being performed with these materials at one or more universities. If we can provide the packaging materials for these foods, our industry can greatly benefit, for the elimination of freight costs on the water component of food may justify a more expensive package ing medium, and the paper industry may thus gain a competitive edge.

KENNETH FISCHER, *Acting Secretary*

Corrugated Containers Division

Corrugated Container Engineering Committee

The meeting was called to order at 2:00 p.m., Feb. 20, 1961, in New York by Vice-Chairman J. Knecht, with Chairman A. Richardson in attendance at the Steering Committee Meeting.

The minutes of the previous meeting held at Toronto, Can., Oct. 10, 1960, were approved as submitted—motion entered by W. Goettsch and seconded by F. Westfall.

Vice-Chairman J. Knecht recognized and introduced the guests.

* Federal specifications also exist, and must be complied with in detail by manufacturers making commodities under federal contracts.

New Members. Vice-Chairman Knecht reviewed the latest appointment of two members to the committee including Philip Ziegler, of Olin-Mathieson Corp., and John Bentley, Westinghouse Electric Corp. Expanded membership of the Engineering Committee was discussed, and after review and election, three proposed new members were elected to service on the Engineering Committee. (Motion made by W. Ward—seconded by C. D. Nitchie.) New members elected are: John Means, Weyerhaeuser Corp., J. C. Thompson, Canadian International Paper Co., and Harvey Stahlsmith, Green Bay Box Co.

The secretary was instructed to prepare letters of welcome to these new members.

Special Report on Performance of Tilt Plate Double Facer. R. Cassady of the Mead Corp. presented a special report on background and experience relative to automatic heat chest control on double facer operation recently installed at the Louisville, Ky., container plant.

Mr. Cassady pointed out by way of background information, that in view of the many variables in operating the double facer such as different grades of paper, different operating speeds, and differences in adhesive, that there is a definite requirement for the ability to control the proper amount of heat application at the double facer. It was pointed out that with the proper control of the heat application, it would be possible to reduce warpage, reduce shrinkage, and washboard effect. Mr. Cassady advised that from his experience it is possible to run the various linerboard absolutely flat.

Supplementary remarks by W. Goettsch of the S. M. Langston Co. pointed out additional details of the system. Of the 29 plates of the hot plate section, 24 plates are controlled in groups of four, and are raised or lowered hydraulically by means of the plates being pivoted on the downstream side of the plates. The plates are lowered with a 1 in. clearance, and indicating lights show the number of sections in use. Both automatic and manual control is available and on automatic control the various groups or sections of hot section are raised or lowered according to the different operating speeds of the double facer.

In answer to questions on the subject, it was pointed out that idle rolls on the double facer had a movement of 0.010 to 0.015 in. and this movement has very little effect on a change of caliper of the board. It was also pointed out that it would be very difficult to modify or add this hot plate control to an existing double facer.

It was agreed that after further study, performance results of this feature would be considered for later presentation before the TAPPI organization.

Report on Project No. 776 (Takeup Ratio). F. Westfall advised that there had been no further data obtained from the Lanzit Corrugated Box Co. and H. Moser of S. M. Langston Co. presented a report on instrumentation and means of measuring takeup ratio and the variables that affect this subject. This report was to be given on the following day before the full TAPPI membership.

After considerable discussion of their comparison of instrumentation method versus hand tachometer method of checking takeup ratio, it was agreed that both methods could be of use to the boxboard plant; however, although instantaneous readings by hand tachometer may be accurate, it should be cautioned that significance may be mistakenly interpreted to other variables.

Engineering Committee Participation on TAPPI Program. Program Chairman R. Hutcheson advised that Engineering Committee would be responsible for additional program time during the main TAPPI Session and advised that the following engineering committee subjects would be presented:

1. Takeup ratio for corrugating medium
2. Waste handling systems survey
3. Heat resistant corrugating belts
4. Corrugator boxboard plant site selection

Program Chairman R. Hutcheson also advised that as part of the general program, a question-and-answer period would be part of the general TAPPI program and the following panel was asked to be on hand to handle inquiries submitted during this question-and-answer period. The panel consists of W. E. I. Davies, T. Haire, R. Hutcheson, W. Goettsch, O. Kleinman, L. W. Kutz, J. Knecht, H. W. Moser, C. D. Nitchie, and A. Richardson.

Abstracts of papers to be presented at the general conference were distributed and individual groups were asked to review and submit additional questions on the papers.

San Francisco Meeting. Preliminary discussion was made regarding selection of theme and subjects for a San Francisco meeting in September, 1961.

Steering Committee Report. Committee Chairman Richardson reported from Steering Committee meeting that it was the intent to avoid specialization in a single theme or subject in order to get broader coverage and attract members of various interests. Chairman Richardson also advised that the October, 1963, general program of TAPPI would have responsibility shared by the Production Committee and the Engineering Committee.

The meeting was adjourned at 5:00 p.m. to be continued the following day.

Engineering Committee Meeting was called to order in the East ballroom at 9:00 a.m. by Chairman Richardson.

Additional discussions covered the various subjects possible for the September, 1961, program and suggested possible subjects were:

1. Special corrugator operations including very long runs and heavy liners.
2. Automatic handling and stacking of sheets at take-off conveyor.
3. Palletizing, unitizing, and special handling.
4. Folder gluer operations.
5. Special steam systems.
6. Foam plastic filler in corrugated.
7. Storage of finished goods.
8. Preventive maintenance.
9. Web alignment equipment.
10. Rotary die cutting.
11. Die mounting.

In discussing general theme and possible speaker, it was agreed that C. D. Nitchie would contact Philip Paul on the West Coast as a speaker on the subject of his own choosing.

L. H. R. McGill was assigned the responsibility of presenting a paper or arranging for a speaker on the subject of rotary die cutting. It was also agreed that W. Goettsch would contact Dan Phillips of Longview Fibre Co. as a possible speaker on the subject of die cutting and serrated blade versus platen-type die cutting.

It was agreed that C. D. Nitchie would contact and arrange for a speaker on various installations and methods of web alignment.

It was agreed that R. D. Merrill will prepare a subject on various types of steam systems.

It was agreed that further discussions and final agreement on agenda of the fall meeting would be settled at the May meeting of the Engineering Committee.

Special Report. L. W. Kutz presented a special report to the committee entitled "Study of Factors Determining Performance in Electrical Drive Systems." The report covered the five basic factors which define and describe drive performance characteristics. These factors being listed below: (1) selectivity, (2) drift, (3) regulation, (4) maximum transient deviation, and (5) transient response time.

In discussing electrical drive systems, open control systems were compared with closed loop control systems and the use of electrical regulators and associated terminology was discussed.

L. W. Kutz, *Secretary*

Engineering Division

Electrical Engineering Committee Interim Meeting

Twenty-six members of the Electrical Engineering Committee and its various subcommittees recently went from all parts of the East to the Greater Pittsburgh Airport Hotel to attend their Interim Committee Meeting.

The various subcommittees and the Steering Committee met on Tuesday, April 11, and the entire Electrical Engineering Committee met on Wednesday morning.

It was announced that P. C. Bobo of The Mead Corp. at Kingsport, Tenn., had been appointed by the president of TAPPI to succeed E. G. Parrish as vice-chairman of the committee. Mr. Bobo had previously been chairman of the Finishing and Converting Subcommittee, which has now been taken over by L. W. Porter, of St. Joe Paper Co., Port St. Joe, Fla.

Three new members were welcomed to the committee. They were: A. Barbaro, of Continental Can Co. in New York; R. H. Hale, of Great Northern Paper Co. in Millinocket, Me.; and L. F. Hayne, of Allis-Chalmers Mfg. Co.

During the meeting of the entire committee, the group finalized their plans for the Washington Engineering Conference in October, and made preliminary plans for the program to be presented at the next conference in Montreal, in 1962.

Chairman Andersen said that he was very pleased with the functioning of the subcommittee type of organization. He said that it is being used as a model for other TAPPI committees to consider. A procedure instruction for operation of the subcommittees is now being prepared.

The next meeting of this committee and its subcommittees will be held during the week of the Washington Engineering Conference.

CECIL L. HARVEY, *Publicity Chairman*

Testing Division

Paperboard Testing Committee

The Feb. 20, 1961, meeting of the Paperboard Testing Committee of TAPPI was attended by 14 members and three guests. Discussion of seven active projects and a review of methods under the jurisdiction of the Paperboard Testing Committee went as follows.

Scoring (Committee Assignment No. 895). Clyde Eckhart distributed copies of suggested methods for evaluation of bending quality of paperboard. The method was reviewed and a motion carried to submit it to ballot after the following revisions were made:

1. A note to be added stating that $1^1/_2$ point rule performance had been studied and data are available, but incomplete.
2. Precision discussion to be reworded to state "test results on duplicate specimens from the same sample should agree within one bender number."

There was some discussion on technique to obtain 35% R.H. for the test. It was generally agreed that this should be decided by individual users.

The chairman instructed that the revised method be submitted for vote through Mr. Burnston with an advanced copy by J. dA. Clark.

Internal Tear (Committee Assignment No. 612). Ward Verseput reported that suggested method had been submitted to vote and was generally accepted but with the following objections:

1. The Paper Testing Committee thought that the CD paperboard method (on semicircular sample) should be included in T 414.

Paperboard Testing Committee: chairman, W. O. Kroeschell, Michigan Carton Co.; vice-chairman, D. E. Marth, Federal Paper Board Co.; secretary, R. C. Williams, Albemarle Paper Co.

2. A suggestion was made to mention T 414 in the suggested method. In discussion it was mentioned that revision of T 414 was not ready for publication. It has been found that line contact clamps provide 10% greater tear than the standard technique in which greater clamping pressure on the bottom of the test specimen is frequently obtained.
3. It was also suggested that pairs of samples be clarified to five pairs tested half facing one direction, half facing in the opposite direction.

It was the unanimous decision of the committee that the jurisdiction question be resolved and that the method be published separately as a suggested method for paperboard.

Breaking Properties of Scores (Committee Assignment No. 905). W. Otto Kroeschell reported that one round robin test with five instruments had been completed and while data were yet incomplete, results were encouraging. Cartons that were tested, however, all appeared to open with ease on filling lines.

Additional data are to be collected and analyzed by the subcommittee. As presently visualized a suggested method will be written covering two different test instruments.

Printability-Compressibility-Smoothness (Committee Assignment No. 617). Ward Verseput said that the project was presently inactive since George Sears (I.P.C.) had tried surface replicas. Dr. Gallay's work with the Vandercook proof press was discussed. The Forest Products Lab work with a zero pressure stylus for profiling was also discussed. It was suggested that the subcommittee have Dr. Sears consider the Schied method in further efforts.

Mullen (Committee Assignment No. 712). Myron Clark (for Fred DeLong) reported that the Container Testing Subcommittee had been working on plain board due to problems with crushing of corrugated structure. It was pointed out that the uniformity of mullen testers must be improved, particularly with regard to elimination of air in hydraulic systems, old diaphragms, and clamping pressure uniformity. Automatic (electric) clamping has been used successfully by some to overcome the latter. New hydraulic systems on mullen testers were said to have an air bleed to help overcome the second problem mentioned above. A method has been written by this subcommittee.

Tensile Energy Absorption (Paper Shipping Sack Testing Committee Assignment No. 769.—Joint Task Force). Bob Williams reported the suggested method has been completed and will be submitted to ballot soon. The application of this test to paperboard was discussed. Several members felt that it was of interest to linerboard (resistance to impact) and possibly to carrier handle strength prediction.

Gluability. Bob Williams indicated that a survey of adhe-

sive, carton, and board manufacturers' approach to gluability determination had been made. It was found that everyone uses a different approach which emphasizes the desirability of such a project. It was also pointed out that the Adhesive Testing Committee was preparing a monograph on adhesive testing and that it might be well to wait and take advantage of this. Harold Ladue volunteered to become chairman of this subcommittee.

Curl. Ward Verseput will act as PBTC representative at the multicommittee meeting on curl. This ties in with the suggested project on roll set. (Incidentally, Dr. Gallay has written an extensive paper on curl in *P & P Mag. of Can.*, Jan., 1961.)

Brightness. Clyde Eckhart will represent the PBTC on the Optical Methods Committee on brightness and optical brighteners.

Photomicrographs. Bob Ragan will be asked to represent the PBTC on work being done on photomicrographs with low angle light.

Miscellaneous. Proposed projects on laminated moisture content and ply bond will be kept on the agenda—but no active work proposed.

Paperboard Testing Methods—Review. Don Marth reviewed 400 series test methods under jurisdiction of the PBTC (according to latest H.Q. chart). Some methods date back to 1944. A list of old methods to be reviewed and revised will be prepared.

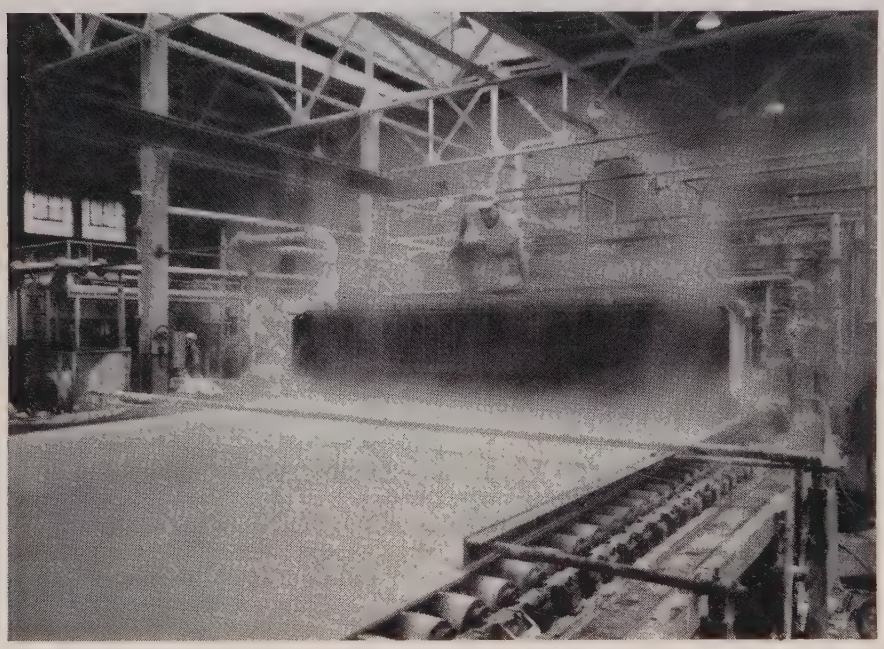
A review of methods *not* under PBTC jurisdiction was given. An attempt will be made to get co-jurisdiction on these methods also applicable to board, particularly ones requiring different procedures on board.

New methods initiated by other committees were discussed and representatives to these were appointed (see curl, brightness, and photomicrographs).

It was considered desirable to have the vice chairman, as a permanent assignment, keep the committee informed of progress on projects, methods, etc., under co- or full jurisdiction of the PBTC.

The next formal meeting will be held during the Testing Conference, Aug. 15–18, 1961, Queen Elizabeth Hotel, Quebec, Que.

ROBERT C. WILLIAMS



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Bound Volume— Technical Section 1960 *Tappi*

Each year the pages of the Technical Section of *Tappi* are accumulated and bound in a cloth cover as a single volume. These volumes are usually ordered by members in advance. There are some copies of the 1960 volume available at $5.00 per copy and may be obtained from the Technical Association of the Pulp and Paper Industry, 360 Lexington Ave., New York 17, N. Y.

ENGINEERING DIVISION

Sixteenth Engineering Conference Theme

The theme of the Sixteenth Engineering Conference is "Economic Solutions Through Engineering" and a number of committees have prepared comments on this theme and its influence in the area of interest of the respective committee: Corrosion, Electrical, Engineering Economics, Fluid Mechanics, and Industrial Engineering and Materials Handling.

Corrosion Committee

Cost reduction is the order of the day. Maintenance costs are of the major controllable cost factors in pulp and paper mill operations. Sound corrosion control practices will reduce maintenance costs in your mill with no impairment of production efficiency.

Hastily conceived or arbitrary maintenance cost reduction programs may reduce costs today, but will eventually lead to lowered product quality and decreased equipment availability. A sound corrosion control program, on the other hand, will yield continuing savings in maintenance cost and will increase equipment performance and availability.

Another important aspect of the corrosion program is the education in the proper selection of materials and fabrication for good corrosion resistance and the ultimate in long life. This requires consideration of over specifying high priced materials which may not be required for a particular job as well as the necessity for not specifying substandard materials which may be cheaper in initial cost but costlier in the long run because of limited life.

The Corrosion Committee of TAPPI is continually working to provide the industry with reliable and economical methods of controlling the costly effects of corrosion. Our program at the Sixteenth Engineering Conference in Washington, D. C., will reflect this objective.

Electrical Engineering Committee

The members of the Electrical Engineering Committee and its various subcommittees are constantly working on activities that cover a wide range of subjects, all of which are aimed to better equip the electrical engineers and plant engineers of the pulp and paper industry to produce a better product at a lower cost.

The drive requirements for mechanical equipment have been studied in order to develop data to permit the use of adequate and efficient electric prime movers. The latter in turn results in an economical installation, since overmotoring can be avoided. The data involved are reviewed periodically so that they can be kept up to date.

The proper application of electrical equipment, including cable insulation, are studied and reviewed with great emphasis placed on actual field experience. The latter is obtained by circulating questionnaires throughout the industry. The information thus obtained is collated and published in a usable form.

All of the completed assignments are published so that they may be available for industry's use in order to obtain the most economical installation.

Engineering Economics

The subject of engineering economics in the pulp and paper industry is the normal application of facts gathered by engineering or technical personnel, and rationalized as to the particular companies situation. The "code of economics" is therefore been one that was fluid and adoptable. In any event the question that most often confronts the middle management group is one that precludes an answer so flexible; conditions of climate, geography, or personalities, do affect the profit picture of all companies, but outside of the scope of these variables there is a continual search for a system which will assign a value number to the projects under consideration, and such systems require use only within the department to drive their maximum value.

The Economics Committee Project No. 929 provides a source of assistance to the members of TAPPI for developing techniques of reviewing their recommendations to management. A quick look at the content of this project, "A Bibliography of Articles Pertaining to Engineering Economics," reveals material of both educational and practical value. The Economics Committee plans to continue this project as well as provide programs with this type of subject matter at the annual engineering conference and other meetings as may be appropriate.

Fluid Mechanics Committee

The Fluid Mechanics Committee is primarily interested in and is directing its efforts toward basic and fundamental research in fluid mechanics as related to the manufacture of the paper product. The early studies were and are directed at characterizing the flow of the pulp-water suspensions at relatively high consistency ranges; i.e., 3 to 6% consistency. More recently the effort has included characterizing the flow of dilute suspensions of fiber in water. Studies have been and are in progress on high-speed free surface flow, which is a study of the flow phenomena that occurs after the pulp-water mixture has been discharged onto the traveling fourdrinier screen. The committee is now endeavoring to assist in programs of flow through porous media which encompasses the problem of draining the water away from the pulp mixture.

The committee members believe that the economy of the papermaking process is, in part, effected by how efficiently large volumes of pulp and water can be pumped through the maze of pipes in a paper mill—how uniform and without imperfections can the flow be guided to the fourdrinier section—how smooth and without disturbance can the sheet of paper be formed on the fourdrinier screen; and—how efficiently can the water be drained away from the pulp fibers. Unless more basic and fundamental information is rapidly developed to add to our present limited knowledge, then the instituting of new methods whose purpose is the attainment of higher levels of production coupled with lower costs, will always remain as long range goals.

Industrial Engineering and Materials Handling Committee

In the fields of industrial engineering and materials handling economics are all important for unless a new method or a new device is economically feasible, such a method or device cannot be purchased by a member firm in the industry unless there is some other required reason for making the change or purchasing the new device.

A primary economic desire can be obtained by reducing labor, producing more with given equipment and labor, or with equipment that costs considerably less to operate than old equipment; or expressed in other words, most economic use of men, materials, and equipment.

Some of the latest developments in the fields of industrial engineering and materials handling include studies of the economic feasibility of data processing for programming operations and also for automatic process control. Many firms in the paper industry are now actively making studies for the various types of equipment available.

New plant sites and new plant designs are now based upon complete engineering studies for the most economic operation, which includes hundreds of factors which must be considered.

In the materials handling field most of the new developments are directed toward automation and mechanization, particularly in-between processes and warehousing. One of the newest ideas for fork truck type handling, for example, are vacuum holding devices. These devices are not yet commercially practical, but when they are will create a completely new handling method.

In the packaging field containerization and unitizing for packaging and shipment of products enables both the manufacturer and consumer to benefit cost-wise through lower packaging costs, lower handling costs, and lower freight costs.

Engineering Economics Committee Bibliography of Articles Pertaining to Engineering Economics

This bibliography is the beginning of a series of publications which will be issued from time to time in *Tappi* as information is accumulated.

It should be pointed out that no attempt to cover the entire field of engineering economics in connection with the pulp and paper industry has been made, but this subject is so current it was felt that an immediate publication of the information gathered to date should be made.

The topics included in this first edition of the bibliography are divided into four classifications according to contents and type, i.e.: (1) engineering economics, (2) specific cost subjects, (3) articles generally related to (1) and (2), and (4) book reviews or digests.

The information included in the various articles listed covers a wide scope of practice from the pure theoretical to specific cost problems. It is felt that the combination of the two will help the engineer to set up the technique and also to find specific similar problems to assist him in setting up and solving economic problems.

People who are directly responsible for making economic studies and reports will find these articles of value in their day-to-day work. Those who are new to the pulp and paper industry will find that a greater appreciation of "dollar-control" technique will speed up the receipt of decisions from top management and receive more favorable action when the program is fully presented.

RAY MARSH, *Subcommittee Chairman, C.A. 929*

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Principles of "On the Machine" Moisture Measuring Systems—TAPPI Project 775

ROBERT B. HURM

This paper describes briefly the measuring principles of those systems of which we are aware in United States. Several European-used systems are also included. Seven different systems identifiable to manufacturer by name are covered. Sketches and diagrams are utilized to clarify where necessary. No claims of builders regarding degree of accuracy, claims of success, or any features other than those relating to the subject of basic principles are covered. It is not the intent of the report to substantiate claims or act as a seller, but rather to clarify and inform. Limitations of usage, specifically as defined by moisture ranges, are a part of the report.

Paper web moisture remains one of the most difficult of process variables to measure. This is largely because all practical means of continuous measurement are indirect or inferential and are affected to a greater or lesser extent by various other process variables such as temperature, composition, basis weight, and pH. No possible method of measurement is universally applicable to all materials and no material is completely free of the extraneous effects of other variables. The most practical method of measurement, therefore, becomes the one that provides the most reproducible results with the materials of interest and at the same time is least affected by other variables known to be present on the process.

There are a considerable number of theoretically possible methods of continuously measuring the moisture content of a sheet of paper. With a view to collecting for the industry certain facts regarding sheet moisture measurement, the TAPPI Process Instrumentation Committee initiated Project 775. The project was concerned with obtaining from the various manufacturers of moisture measuring equipment special write-ups of those principles upon which their systems are dependent. This presentation is in reality a report of the principles as gathered by the chairman of this project, who is acting on behalf of the aforementioned TAPPI Committee.

The presentation will attempt to define the measuring principles of the systems of which we are well aware in this country. Several foreign-made systems are also included herein.

No claims of builders regarding the degree of accuracy, claims of successful installation, or any features other than those relating to the subject of the basic principles involved are covered in this report. It is not the intent of the report to substantiate claims or particularly act as a seller, but rather to clarify and inform.

It should be pointed out that the information contained herein does not represent any original work by the author or by the committee, but is rather a collection of those facts and principles pertaining to sheet moisture measurement.

THE HURLETRON MOISTURE CONTROL

The Hurletron moisture control senses sheet temperature under controlled conditions to measure the moisture content of paper and paperboard. Gaging is performed at the end of a drier section just ahead of a size press, calender, or reel. Several gages are spaced across the sheet at 18 to 24 in. increments to measure machine direction variations at each point, thereby detecting profile variations as well.

One of the last driers of the section should be valved and trapped to operate at a fixed steam pressure. A constant temperature is developed in the drier; any superheat in the supply steam is removed by the liquid condensate inside flashing into steam to maintain saturated temperatures. As the sheet contacts the reference drier, the remaining process water in its fibers (moisture) is heated by conduction and radiation to 212°F. This is the maximum temperature that can be developed, establishing in the sheet a pre-measurement standard. The inverse relationship between basis weights and machine speeds puts a uniform load on the drier. All sheets between 0 and 15% moistures are raised to 212°F. even though the speeds are varied during a run.

When the sheet parts from the reference drier, vaporization of moisture continues at a violent rate for the first 8 to 10 in. This change of state lowers sheet temperature sharply. At 28 to 30 in. from the drier, Hurletron sensing elements (Fig. 1) contact the sheet and measure the temperatures with five thermocouples protected by a stainless steel wear-plate. Another five thermocouples measure the drier temperature, these having a copper wearplate. By wiring the ten thermocouples in series opposing, those on the drier form the hot junctions, and those on the sheet are the cold junctions. This arrangement senses temperature differences; it also increases the output. By adjusting reference drier temperature, output signals can be regulated to suit instrument calibration. As moistures vary from 0 to 15%, the temperature drop varies from 0 to 75°F. and the output signals vary from 0 to 8 millivolts.

Measurement is precise because the critical factors are closely controlled. Reference drier pressures are controlled without deviation. Initial sheet temperature on the drier is 212°F. The distance from drier to point of measurement is fixed by the mounting attached to the frames (Fig. 2). Other factors are unable to affect the sheet temperature at the elevated temperatures. Rate of speed is offset by the basis weight or mass of the sheet. Hurletron measurement is not affected by normal variation in type of pulp, degree of refining, additives, color, pH, weights, caliper, tension, speed surface conditions, room conditions, and sizing. When clay coatings are applied to printing grades, calibration does not change from C1S and C2S grades, nor for various coating weights.

The output of each gage is connected to potentiometer

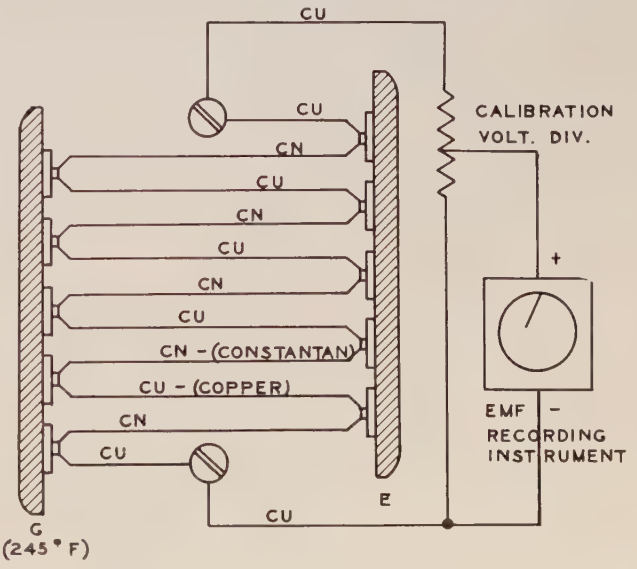

Fig. 1. Diagram of Hurleton thermocouple moisture gage

Robert B. Hurm, Staff Engineer, Beloit Iron Works, Beloit, Wis.

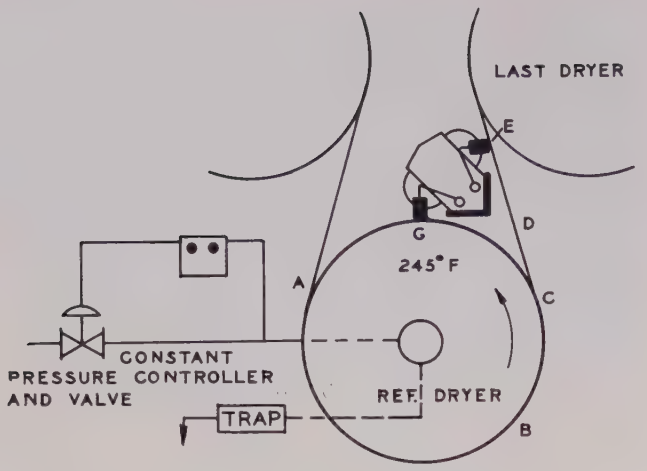

Fig. 2. Location of gage in machine driers

type instruments. A multipoint recorder sequentially prints the data on a chart to record profiles. One of the gages is connected continuously to a pneumatic controller which regulates a steam valve that establishes correct drier temperatures for drying the sheet to the desired moisture content in the case of control (Figs. 3 and 4).

ATROMETER MOISTURE MEASURING PRINCIPLES

Hygroscopic Type

The original Atrometer moisture meter was developed in 1949 and was made as a hygroscopic type (Fig. 5).

It is a well-known fact that a moving web of paper carries with it a moisture film which is in direct ratio to the amount of moisture in the sheet and by using this phenomenon, the hygroscopic feeler was developed. This particular instrument can measure a moisture content between 1 and 25% with the accuracy remaining constant over the whole measuring range. The instrument is independent of temperature and voltage fluctuations and the time lag is within a permissible allowance. A number of these were installed in the United Kingdom, Sweden, Finland, Germany, and Italy. This method does not require actual contact with the moving web.

The feeler, or sensing element, consists mainly of a heat resisting hygroscopic rod which changes its resistance rapidly with respect to electric currents as it absorbs more or less moisture from the air film rising from the paper sheet. The element is housed in a perforated aluminum casing which permits the air stream to flow freely around the element. The small variations in electrical resistance cause changes in current which are amplified and shown on the indicator and registers on a recorder. The feeler is fitted in a fixed position. Any number of additional feelers can be fitted, each of them containing its own electronic channel.

The amplifier used is a simple electronic type. It contains two variable resistances used in the calibration, one for finding one end point of the scale (maximum moisture) and one for setting the other range (minimum moisture). After

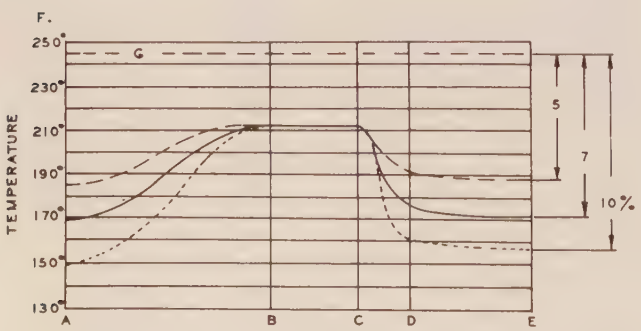

Fig. 3. Sheet temperatures on and following reference drier

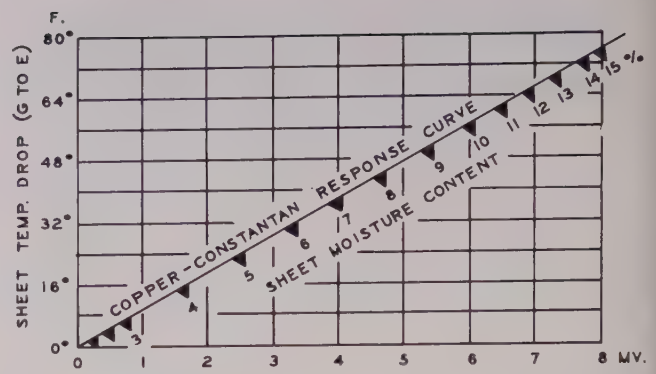

Fig. 4. Millivolt output of gage to recording instrument

calibration, the scale on the indicator permits direct reading of the moisture percentage.

In the multifeeler type, each feeler has one indicator but the recorder shows the average measure of the moisture content measured by all feelers.

One advantage claimed for this type is that it is unaffected by paper machine speed or static from the paper. There is, however, one disadvantage, and that is that the instrument requires recalibration about every 3 months due to the feeler element getting contaminated when a stack might be hosed with kerosene or water. This causes the instrument to respond slowly to changes in moisture. Another source of contamination is from pitch which builds up on the sensing element. This also causes a slow down in the response.

This type is recommended where the feeler cannot be brought into contact with the paper web. However, it must be accepted that the feeler element must be replaced three to four times per year.

Electrostatic Type

This Atrometer (Fig. 6) is available with up to 30 feelers which may be located at any desired interval across the width of the web. With this arrangement, the operator can instantly check the humidity distribution across the entire web width. It consists of a feeler complete with cable, amplifier, and panel with recorder, etc.

Using the principle of static field measurement, a condenser, charged with high voltage develops a static field on the layers of the condenser plates to an effective depth of $^1/_2$ in. Utilizing the static field for the determination of humidity, the Atrometer is independent of the basis weight or the feeler contact pressure on the web. As the humidity in the paper changes, so does the static field; thereby, the condenser discharges varying amounts. The remaining charge in the condenser is used to cause fluctuations in the electromotive force on the grid of the electronic tube and so indicates the humidity on the instrument dial.

This device can measure a moisture content up to 50%.

The feeler may be made as a show or roller and requires only a very light contact on the web. Feelers can be supplied in any length 20 in. maximum to 10 in. minimum; 20 in. length is standard. Special adjustable suspension is supplied so a minimum weight is on the web, sufficient only to stop the feeler from bouncing, yet insures good contact at all times.

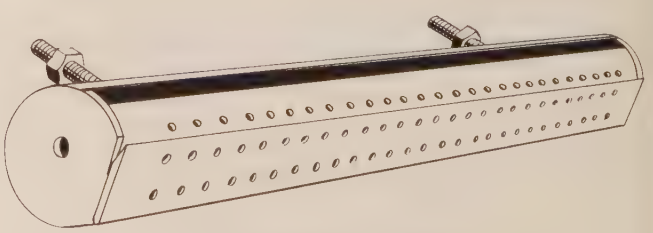

Fig. 5. Hygroscopic feeler

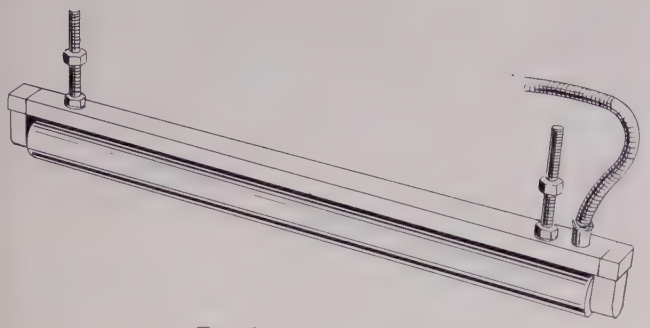

Fig. 6. Roll-type feeler

It is claimed unaffected by changes in furnish, voltage fluctuations, or basis weight. The time lag in the signal of the moisture changes is practically nil, and this instrument can be setup in various positions. The feelers can be fitted end to end with only $^1/_4$ in. space sufficient to allow the free movement of each feeler.

Repeater indicators and recorders can be installed in any position where they are required. There are no restrictions to distance, and the indicators provided are large size and can be read easily by normal paper mill lighting up to distances of 30 ft. A strip chart recorder may be used with this device. The position of the amplifier is governed by the length of the cables on the feelers. The longest cable is approximately 33 ft., each cable being 3 ft. shorter than the previous one. The feeler is fitted with special insulation and can be used in ambient temperatures up to 250°F.

In summarizing, claims of this principle are listed as follows: (1) unaffected by furnish changes, (2) unaffected by basis weight changes, (3) uncontaminated by pitch pickup, (4) uncontaminated by water hoses or stacks hosed with kerosene, (5) easily calibrated, and (6) unaffected by machine speed or variation.

STAMM MOISTURE CONTROL SYSTEM PILOT DRIER TYPE

The Stamm system (Fig. 7) uses one of the regular paper driers as a "pilot" or "indicating" drier. This pilot drier is located near the dry end of one of the paper machine drier sections, where control of the moisture is desired. For example, it may be in the drier section ahead of a size press, a coater, and of course, ahead of the reel.

The pilot drier is very sensitive to small changes of moisture in the sheet. It feels the sheet across the entire width of the machine and, therefore, gives an average indication of moisture variation. It is held at constant steam pressure, independent of the rest of the driers.

The sheet, passing over this drier, absorbs heat from the surface, and obviously, the damper the sheet the greater the rate of heat transfer. Thus, the moisture content of the sheet directly governs the rate of steam flow to this drier. The principle can be simply stated: "The moisture content varies directly with the thermo capacitance of the sheet."

The moisture indication is a steam flow indication to the pilot drier. Several systems of indicating the steam flow may be used. The two systems generally offered are: (1) at the pilot drier, a manually adjustable diaphragm valve orifice, together with a differential pressure transmitter provides the stream flow measurement; (2) a fixed orifice, together with a steam flow transmitter provides the steam flow measurement.

The adjustable orifice arrangement permits changing the ranges of the moisture control if the paper machine is subject to extreme changes in weights and moisture. The fixed orifice type is used on machines not subject to such wide variations.

The equipment used at the pilot drier, on the steam supply to the pilot drier is as follows:

1. A primary steam reducing valve and controller.
2. The valve orifice with the differential pressure transmitter, or an orifice with a steam flow transmitter.
3. Another reducing valve with a recording pressure controller.

The drier discharge may be equipped with a steam trap, or an adjustable orifice sight glass assembly.

At the main control panel, there is the main stream pressure or temperature controller, the automatic moisture controller, the transfer station and, when used, the loading station for changing the valve orifice.

The system is available in most popular makes of instrumentation. Therefore, the main panel appearance and equipment can vary with the particular instrumentation desired.

The automatic moisture control system holds a constant steam pressure in the drier section as long as the sheet remains constant in moisture. However, when the moisture in the sheet changes, the variation in steam flow to the pilot drier will automatically reset the moisture control unit for a higher or lower steam pressure in the machine header as required, to meet the demands of drying sheet.

Constant pressure control is used as a manual control during periods whenever the sheet is off the machine. This operation can also occur when warming up the machine, and during paper breaks.

BROWN MOIST-O-GRAPH SYSTEM MEASUREMENT AND CONTROL OF MOISTURE IN PAPER BY THE ELECTRICAL CONDUCTIVITY METHOD

Of the considerable number of theoretically possible methods of continuously measuring the moisture content of paper, the electrical resistance or conductivity method has been one the most extensively used. Some advantages claimed are simplicity, reliability, reproducibility, applicability to most types of paper, and relative insensitivity to basis weight changes.

The electrical conductivity method of moisture measurement is based on the fact that for many materials, including most types of paper, a highly reproducible relation exists between the moisture content of the material and its electrical

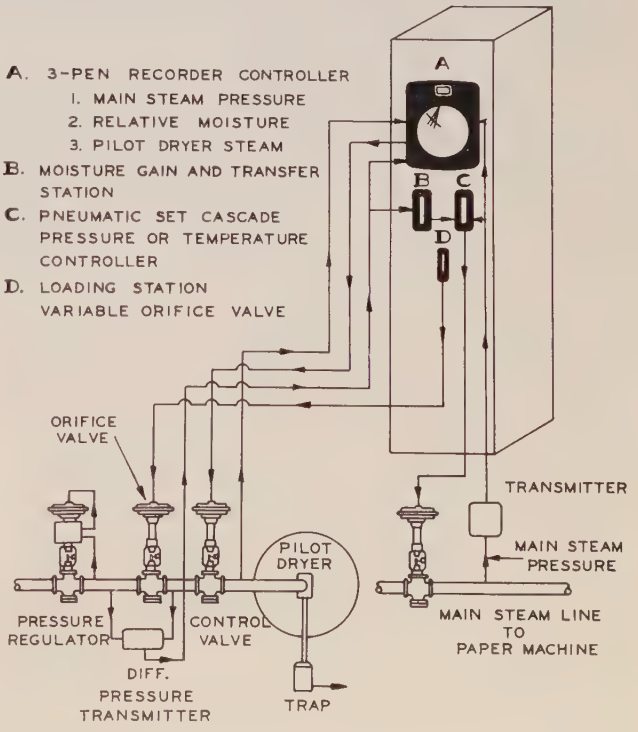

Fig. 7. Stamm moisture control system

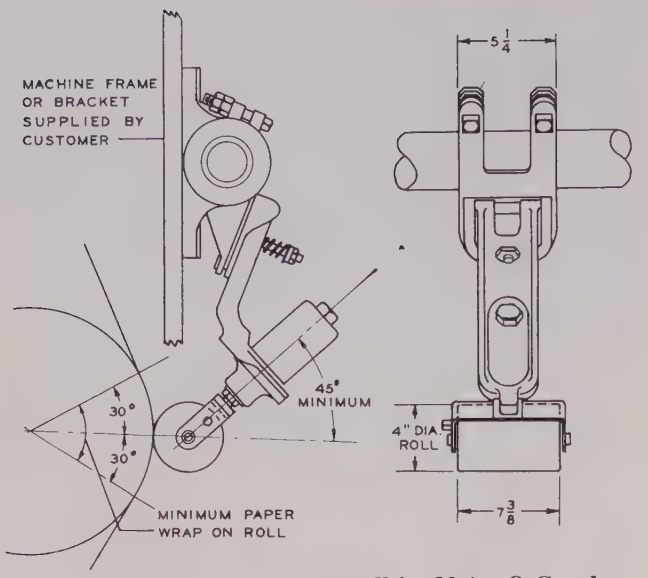

Fig. 8. Installation of detector roll for Moist-O-Graph on paper machines

resistance. This relationship has been proved by extensive tests of numerous investigators. Although the electrical resistance of different materials at a given moisture content may differ considerably from material to material, papers of a given type and furnish will all have essentially the same electrical resistance. Further, the electrical resistance of a given material or paper at a given moisture content is highly reproducible.

The electrical resistance of most papers in the range of moisture contents of usual interest is between approximately $^1/_2$ and 5000 megohms. Resistances of these magnitudes are readily measurable by conventional resistance bridge methods. Electronic means are incorporated to provide a high degree of sensitivity and accuracy.

Satisfactory measurement of moisture content below approximately 2 or 3% is not generally expected with the conductivity method because the electrical resistance usually becomes quite high and other variables start to adversely affect the measurement. Similar limitations, however, also apply to many other methods of moisture measurement. Satisfactory measurements have been made on some papers with moisture content as high as 40%.

A typical moisture calibration is spread out at the center of the instrument scale, and is compressed to some extent at both ends. A multirange switch permits placing the desired moisture content at or near the center of the instrument scale. Near the center of the instrument scale, a span of 1% of moisture may cover approximately 20% of the instrument scale. A typical moisture record will prove to be quite a surprise to those who have not previously observed a moisture record. It is a noisy, somewhat erratic appearing record that bears no relation to the usual smooth temperature record. This results from the fact that there are some longitudinal moisture variations even in the most uniformly dried papers, and the fact that these variations of only a small fractional percentage of moisture content represent a number of per cent of instrument scale. This basic nature of measurement presents some problems to the moisture control system. It also makes the use of multi-record print wheel type of instrument unadvisable except under unusual circumstances. Usual practice is to employ a single record pen-dragging type of instrument.

The Brown Moist-O-Graph system is based on the electrical conductivity method of measurement. It is conventionally supplied as recording only, recording and signaling, or recording and controlling. The measuring and recording portions of this system are essentially identical on all three systems.

Principle components of this system are the detector element, the electronic measuring unit, the moisture recording control instrument, the secondary temperature or pressure control instrument or instruments as used in cascade systems, a lock-out timer, selector switches, pushbuttons where required, signal lights, and the final control element which is usually a steam valve. All of these components except the detector element and the final control element are mounted on the panel or cubicle.

The detector element consists of a stainless steel roller approximately 6 in. long and 4 in. diam. supported by a porcelain insulator. The detector element is installed so as to roll on the paper over a grounded machine roll in such a manner as to permit the measuring circuit current to flow from the detector roll through the paper to the grounded machine roll and back to the measuring circuit. Thus the paper sample which is continuously moving under the detector roll becomes a series resistance in the circuit and its magnitude is continuously measured by the measuring circuit.

One or more detector elements are installed across the width of the sheet. Common practice is to use up to six detector elements which are connected to the measuring circuit by means of a manually positioned selector switch which is mounted on the Moist-O-Graph panel or cubicle. Although it is possible to control from only one detector element, this arrangement permits periodic checking of the moisture content across the width of the sheet to assure that uniform drying is being obtained. Although the moisture measuring and control system may be capable of detecting and locating wet areas across the sheet, it cannot correct the condition. It can only raise or lower the general level of drying.

The detector rolls are mounted on a supporting shaft across the width of the machine in such a manner that they can easily be swung up out of the way for ease of machine threading.

Because the electrical resistance of the paper being measured is quite high, extremely low leakage insulation is required for the detector rolls and the cables connecting them to the instrument. A special detector roll cable is supplied for this purpose and care must be exercised to maintain it in good condition.

Proper control of the moisture content of paper on a paper machine presents some control problems. This is in part because of the inherent noisy nature of the moisture record, and in part because of the relatively long time lag between the time corrective action is instituted and the time the result is felt in form of a moisture change at the element.

The most satisfactory control action has been obtained by use of a proportional and reset type of cascade control system in which the moisture measurement is used to reset the set point of a temperature controller regulating the steam supply to the last section or sections of the dryer.

A paper break switch, which is a limit switch installed on the machine and operated when the paper breaks, wired into the system to lock out control action during the break or other machine stop.

In order to place moisture recorders in proper recording range, all transmitters are provided with a five position range selector switch. Figure 8 shows the installation of a typical paper Moist-O-Graph detector roll or sensing element on a paper machine roll.

THE HYGROTESTER*

Many instruments are manufactured to measure capacitance. The operating principle here is based on the change in the dielectric constant (specific inductance) of the paper between high and low moisture contents (Fig. 9). Since the dielectric constant for paper is very low, in the region of 2.8 to 3.0 for oven dried samples, and for water around 80, then a small change in the moisture of the sheet will produce a considerable change in the dielectric constant. This factor

* Also known as the Lippke Supertest.

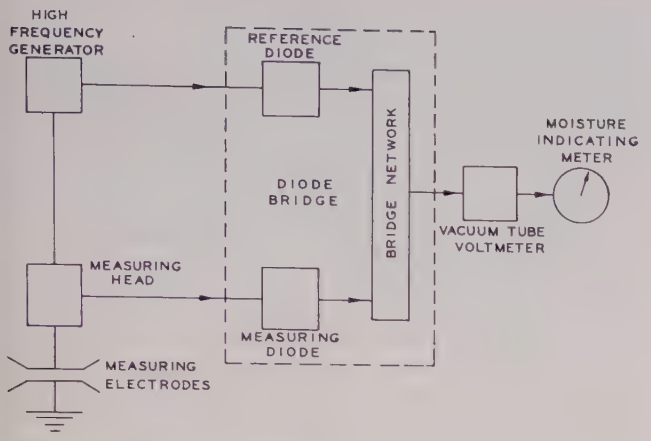

Fig. 9. Schematic diagram of the Lippke supertest

makes it possible to utilize capacitance to determine accurately the moisture content of the sheet. Since the measuring cell area and spacing of the electrodes remain the same, any changes in moisture will influence the dielectric constant which will vary the measured capacitance of the circuit. The change in capacitance for each 1% change in moisture varies depending on the weight and furnish of the sheet, but on kraft papers an increase of moisture by 1% will produce a capacitance change of 7 to 8%.

When capacitance and inductance are coupled in parallel and an alternating voltage is applied to the combination at their resonant frequency, a maximum voltage is developed. If the applied frequency is held constant, but the capacitance varies, the resonant frequency of the combination will change and the voltage developed will alter.

This is the principle of the Hygrotester. The measured capacitance changes due to variations in the dielectric constant of the paper web, which is a function of the moisture content of the sheet. This results in a variation in voltage across the parallel-tuned circuit. These variations are measured by high impedance vacuum tube voltmeter and, by suitably calibrating indicating meters, a direct reading of moisture content of the web is achieved.

The high-frequency generator provides a stable frequency signal. This is applied simultaneously to the measuring head and the reference diode. The output from the diode provides a stable d.c. reference voltage which is applied to one side of the bridge network. The output from the measuring circuit is fed into the measuring diode, the output of which is a varying current proportional to the dielectric constant of the web. This is applied to the other end of the bridge network. By selection of suitable tapping points, it is possible to extract from the network a varying voltage which can be applied to the valve voltmeter. Since variations in basis weight of paper will produce a change in the dielectric constant, it is necessary to compensate for these variations in the main voltage. This is done by installing a calibrated potentiometer, set to the basis weight being produced, which insures that the two voltmeters will measure only the voltage changes due to the moisture variation of the paper web itself.

The nucleus of any arrangement for determining moisture by measuring the dielectric constant of the material involved is the measuring capacitor. The double plate capacitor, which is suitable mainly for dealing with easy flowing and liquid products, is not suitable for flat materials, being replaced by a spray field capacitor, the electrodes of which are in the same plane. The lines of flux which lead from the plates having the same polarity to those plates of opposite polarity are influenced by the paper web being measured. As a result, the capacity of the entire arrangement varies. The changes in capacity, which now arise as a function of the variation in moisture content, are detected by a high frequency measuring device and are indicated. Such a moisture content measuring system can be subdivided in the following components:

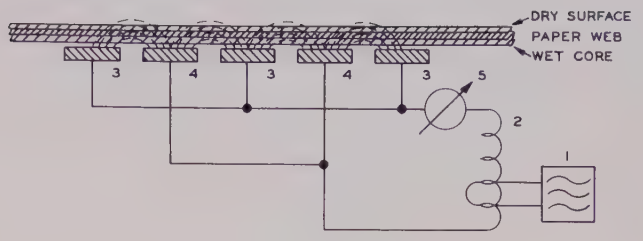

Fig. 10. Moisture measurement

1. High frequency generator with power supply.
2. Measuring circuit with measuring capacitor.
3. Indicator with widely different types of measuring and recording devices.
4. Diode bridge circuit containing reference diode, measuring diode, and bridge network.

Figure 9 indicates the schematic diagram of the Hygrotester system.

Figure 10 indicates the method of moisture measurement with the flat capacitor.

AQUATEL MOISTURE SYSTEM

The Aquatel measures per cent moisture of sheet and bulk products in the low moisture range. By measuring the a.c. conductivity of the product, the Aquatel gives per cent moisture measurements claimed unaffected by changes in other product variables (Fig. 11). Linear response to per cent moisture over prescribed moisture ranges is available. For bond papers and paper boards, a 5% range is generally available within the limits of 3 to 10% moisture. A 5% range is generally available for newsprint and kraft papers within the limits of 3 to 11%. Reference to Fig. 12 will show variations of resistance with moisture change for several types of paper.

Theory

The principle of measurement is based on the change of a.c. resistance of the product with moisture. The resistance of the product is approximately given by:

$$\log R = K - CM$$

where

K and C = constants determined by the product and the electrode configuration
M = percentage moisture
R = resistance

Then the percentage moisture is:

$$M = \log R - \frac{K}{C}$$

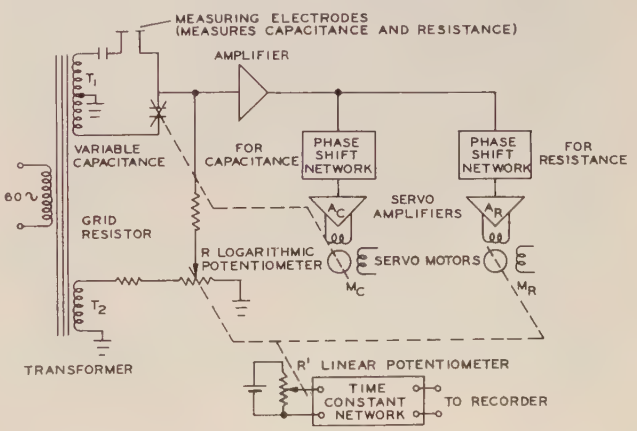

Fig. 11. Block diagram—moisture measurement system

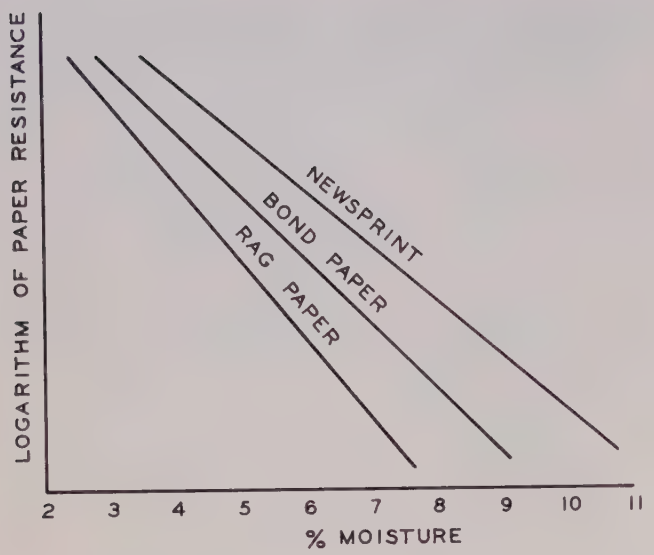

Fig. 12. Chart showing variations of resistance with moisture change for several types of paper

Thus, if R is a logarithmic potentiometer, then by coupling R to a linear potentiometer, we can generate a signal linearly related to the percentage moisture.

To simplify the explanation and understanding of the moisture gage, reference should be made to attached block diagram of the moisture measurement system.

The primary loop is split into two sections:

1. The R (resistance) balance servo loop.
2. The C (capacitance) balance servo loop.

The R balance servo loop consists of the following main parts:

A. The special logarithmic potentiometer. (Note: Some models use a step switch with fixed resistors arranged logarithmically.)
B. The cathode follower amplifier (common to both R and C).
C. The R phase shift network.
D. The R servo amplifier.
E. The R servo motor driving the log resistor and linear retransmitting potentiometer.

The C balance servo loop consists of the following main parts:

A. The measuring capacity bridge.
B. The common cathode follower.
C. The C phase shift network.
D. The C balance servo amplifier.
E. The C balance servo motor driving the balancing capacitor.

When the measuring electrodes come in contact with the product, a resistive and capacitive current flows through them. This current produced an a.c. voltage across the grid resistor of the cathode follower amplifier. Also coupled to this grid is a variable capacitor and a variable voltage supply. The voltage supply is of the resistance phase, and is generated by a logarithmic potentiometer on the bottom of the resistor.

Varying the capacitor creates a current opposite in direction to the capacitive current flowing through the electrodes. Adjusting the log pot creates a voltage of opposite phase to the voltage developed across the grid resistor by the resistive current flowing through the electrodes.

It is therefore, possible to null out the capacitance and resistance current created by the product, by adjusting the setting of the variable capacitor and the logarithmic potentiometer.

If an unbalanced signal exists from either a capacitive or resistive current, a voltage will be produced at the output of the cathode follower, and fed into each of the servo balanced chassis. It is desired that if the voltage is from resistive error (0 or 180° face from line voltage) the R balance motor will run, and if the voltage is from a capacitive error ($\pm 90°$ face) the C balance motor will run.

A two-phase servo motor will run only when the voltages which are 90° out of phase are applied to the two windings. If an in-phase (0 or 180°) is fed to the control winding the motor does not run but merely heats up.

The direction of motor rotation depends upon whether the control voltage leads or lags the line voltage by either $\pm 90°$. The servo motors are used as the phase rejection devices.

The voltage phasing between capacitive and resistive error is always separated by 90°, so we adjust the phase network on the R servo balance chassis so that a capacitive error is in-phase at the amplifier input. Therefore, a capacitive error produces no torque on the R balance motor.

The phase shift on the C servo balance chassis is adjusted so that a resistive error is in-phase at the amplifier input and produces no torque on the C balance servo motor.

Because of the 90° phase shift between R and C error signals, the R servo motor will run only in response to an R error, and the C servo motor will run only in response to a C error.

In actual operation both R and C errors exist simultaneously, but the servo motors separate the phases when their control voltage has been phased properly.

The log pot is fed with a variable a.c. from the grade control, and the setting of this determines the position of the percentage moisture divided by log R curve. This becomes a function of the various weights.

As stated before, the R servo motor also drives a linear pot wiper, connected across a stabilized supply of d.c. Hence, the voltage output of this wiper is proportional to the rotation of the log R pot, this voltage being fed to the adjustable time constant circuit. Here it is smoothed of all erratic variations and fed to the recorder, calibrated in "per cent moisture."

The detector head mounted on the O frame carriage has three teflon insulated metal electrodes pivotedly mounted on a solenoid-actuated arm. When power is applied to the solenoid the arm moves toward the sheet placing the electrodes in contact with the paper. During the time the head is off the web, power is removed from the solenoid so that the head will not break the sheet.

The calibration of the instrument requires two settings, grade, and slope. The slope of the product is determined by the basic fiber in the sheet and by the type of pulp, the bleach and to some extent, the coating. The slope is described as a ratio a.c. resistance change for a 1% increase in moisture. The value for paper usually varies between 3 and 5% moisture. The grade is a setting for the actual value for the a.c. resistance of the sheet, and its value usually ranges from 10^8 to 10^{10} ohms at 5% moisture. The grade setting will change with basis weight, type of coating and fiber, and to a lesser degree, finish, and speed.

Because most paper machines are specialized, it has been found that slope changes only slightly over the complete range of sheet produced by that machine, therefore, a grade setting is all that is required when a new product weight is run.

THE FOXBORO SYSTEM OF MOISTURE MEASUREMENT

Laboratory Tests

The initial studies were made on pure alpha-cellulose paper moistened with distilled water. Thousands of measurements were made of both resistance and dielectric constant as moisture was varied from moisture free condition to 12% moisture content at constant temperatures in the ranges between 80 and 180°F. The effect of varying basis weight as it affected dielectric constant and resistance results were investigated over a wide range.

These measurements were made at audio-frequency, that is, 5000 cycles per sec., to take advantage of latest instrumentation developments. The element used in these in-

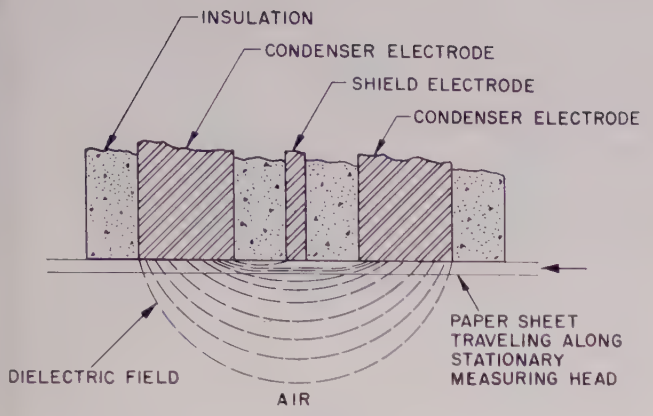

Fig. 13

vestigations was an annular capacitor in which the samples under test could be kept under absolute control at all times. The resistance was measured as dielectric loss; and the dielectric constant as change in effective capacitance of the element due to the presence of the sample.

Examination of the data resulting from these tests seemed to indicate that either the resistance or dielectric measurement might be expected to be satisfactory for the determination of moisture content of paper. There was no strong reason for selecting either one over the other. It was decided, therefore, to make practical on the machine tests of both resistance and dielectric constant to see if any differences would show up which would lead to the selection of one of them for a moisture measuring system.

On the Machine Tests

A dual purpose instrument was designed and built to measure simultaneously the in-phase, resistance, and quadrature, capacitance components of a 5000 cycle signal from a specialized one sided measuring element, to be described later. With the construction of this instrument, the research activity moved into the machine rooms of various paper mills.

After months of recording, and careful checking of correlation between measurement and laboratory moisture test, the accumulated data was subjected to analytical study. It became apparent immediately that the correlation between measured capacitance and moisture content of paper as run on a paper machine, was significantly better than the resistance measurement. This was found to be true in similar tests at more than one paper mill. It was concluded that the difference between the results on the alpha cellulose with distilled water and paper as run on a paper machine must be due to variations in the electrolytes inevitably present in varying types and amounts in the white water in a paper mill.

Paper Moisture

The measurement of moisture in the traveling web of paper as it is produced on a paper machine illustrates a typical form of dielectric constant monitor applied to a continuous flow of solid material. Early experiments were carried out using a pair of fixed, parallel plates, between which the paper was passed. It was necessary to provide very accurate spacing of the plates. In case of a break of the sheet, threading of the paper through the plates was difficult. Particularly in high-speed news machines, where the speed of the sheet may run better than 2000 f.p.m., a parallel plate structure became clumsy and undesirable. Because of this, a spray-field type of measurement was developed whereby a structure placed on one side of the sheet accomplishes the measurement.

Reference to Fig. 13 shows a diagram of this spray-field type structure. The electrodes are supported in an insulating structure but with a thin shield plate located between the two measuring electrodes. As is shown in the figure, a spray-field is developed in the space outside the electrodes and the shield. There is obviously a large capacitance from each electrode to the shield plate passing through the insulating material. On the other hand, all the actual field between the two electrodes passes up and out as a spray-field. This spray-field originates at one electrode, passes up through the sheet to be measured, then through the air behind the measured sheet, back through the measured sheet, and into the other electrode. Changes in the dielectric constant of the measured material have a relatively large affect on the capacitance between the measuring electrodes. A special circuit, which will be described later measures sprayfield only, variation of dimensions or dielectric constant of the insulating material separating the electrodes and shield plate has negligible effect on the measurement. Furthermore, the large distributed capacity which would exist between electrodes without the shield is eliminated. The relative change in capacitance between electrodes due to a change in dielectric in the measured material is large. In actual practice, the electrodes are about $^1/_{32}$ in. width and are spaced with about $^1/_{16}$ in. center distance. In a typical measuring head, five electrodes, three of one polarity and two of the opposite polarity, are employed. Figure 14 shows a partial view of the head structure. A head of this type will have approximately 20 mmf. capacitance in the field between the electrodes with no paper passing over the head.

Moisture in paper and other cellulose material differs markedly in its behavior from a dielectric standpoint from

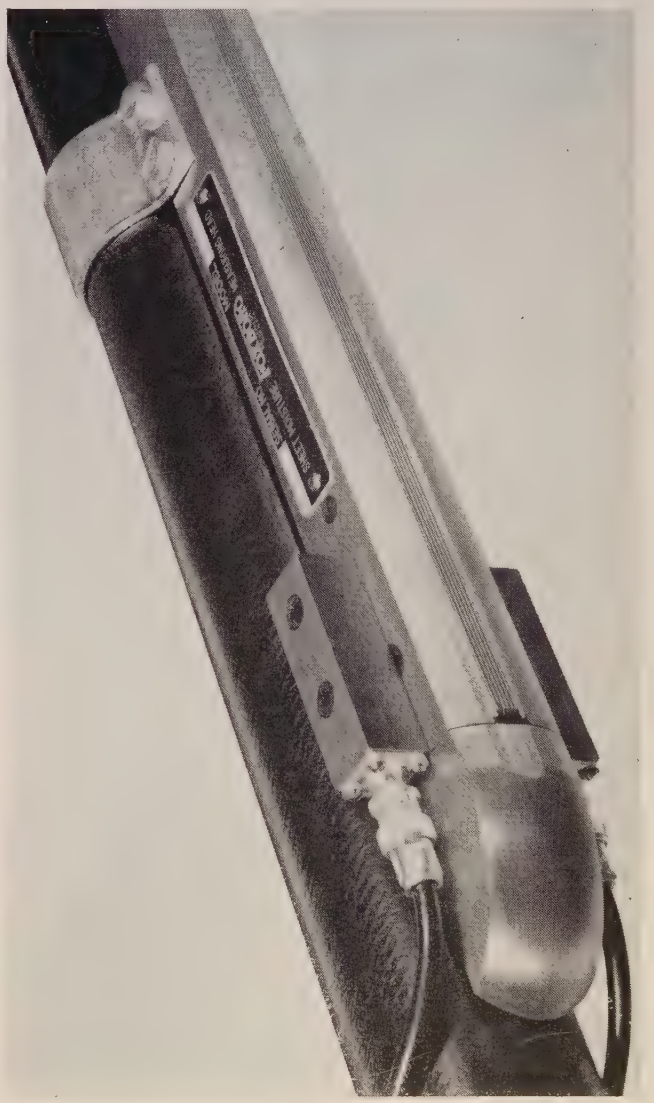

Fig. 14

either in-solution or emulsion in spherical droplets. Actually, the water collects in the five cellular structure of the fibers. This water may be considered to be a group of microscopic filaments or wires randomly disposed throughout the material. At low moisture contents, these filaments are comparatively short; as the moisture content increases, the conducting paths become longer and link up with each other. As a result of this structure of the water as it occurs in a sheet of paper, the effect on dielectric constant is large. One per cent of water increases the dielectric constant by from about 6% at low moisture content to about 20% at high moisture content. The highest moisture content effectively measured by this technique is not established. However, measurements for the normal working range between 4 and 15% sheet moisture content have been successful. Of course, the total capacitance of the capacitor is affected both by the thickness of the sheet and by its dielectric constant. Changes in basis weight thus inevitably affect the reading. However, at a moderate moisture content, where a 1% change of moisture produces a 10% in change in dielectric constant at $\pm 2^1/_2\%$ change in the basis weight of the sheet produces a change equivalent to $^1/_4\%$ change in the moisture content. On a well-run paper machine, the variations in apparent moisture due to a change in basis weight while not entirely negligible, are tolerable.

Figure 16 shows a diagram of the capacitance measuring circuit used. This is a special, voltage division or modified bridge circuit operating at 5000 cycles rather than a resonant

Fig. 15

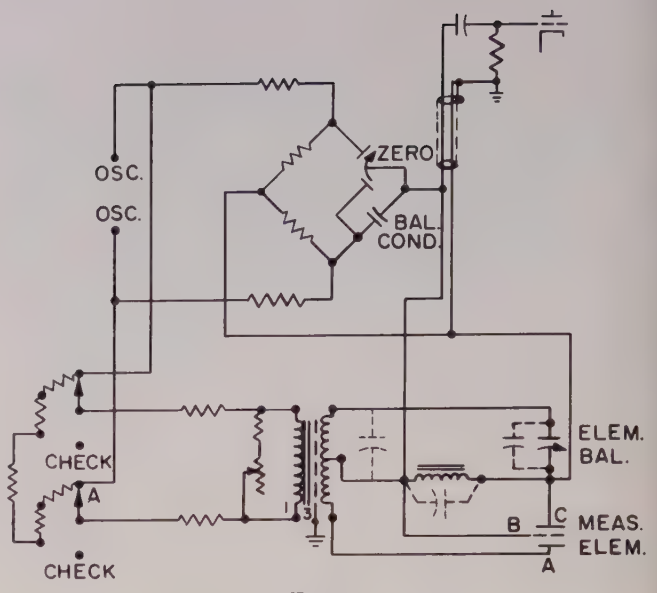

Fig. 16

radio frequency. A 5000 cycle oscillator supplies energy to a special transformer, with a center tapped secondary winding which is designed to have a minimum of inductance leakage between the two halves of the secondary winding. The center tap of the winding is connected to the shield plate. One end of the winding goes to one electrode of the measuring capacitor; the other end of the winding goes to one terminal of an insulated, balancing capacitor having approximately the same capacitance as the measuring capacitor.

Any capacitance or leakage resistance between shield plate B and the lead from the transformer to the electrode A of the measuring capacity, may be considered as shunt impedance connected across that half of the secondary winding of the transformer. Since the impedance of the winding is relatively low, and the coupling between the two halves of the winding is very tight; capacitance or resistance between this lead and the shield plate has a negligible effect on the balance of the circuit. The second electrode C of the measuring capacitor is connected to the second terminal of the balancing capacitor; this connection is grounded. A lead from the common connection between the shield plate and the center tap of the transformer is brought to the null detector system in the instrument and constitutes a signal lead.

This signal lead will be at the potential (ground) of the common connection between the balance and measuring capacitors when these capacitances are equal. Assuming this lead is at ground potential, then zero potential will be applied to any capacitance or leakage resistance between this lead and ground. Stated another way, by maintaining a balance in this system, capacitance or leakage resistance between this signal lead and ground will have a negligible effect on the instrument.

On the other hand, any small difference between the capacitance of the measuring capacitor and the capacitance of the balancing capacitor will result in a change in the potential in the entire transformer winding, including its midpoint which are connected the shield plate and the signal lead with respect to ground. This small potential is amplified and operates a suitable rebalancing motor, driving the pen or pointer of the instrument and at the same time adjusting the value of the rebalancing capacitor. A study of this circuit shows that it provides for measurement of capacitance variation between the electrodes of the measuring capacitor and is essentially independent of capacitance or resistance between shield and either or both electrodes or electrode leads. In practice, the insertion of a capacitance of 10,000 mmf. between either electrode and the shield has an effect upon

measurement less than that from 1 mmf. capacitance change between electrodes.

With this circuit, a triaxial cable is used to connect the measuring head to the instrument. The dore of the triaxial cable is connected to one of the electrodes, the outer braid to the grounded electrode. The intermediate braid shielding is connected to the shield plate which eliminates the capacitance effect between the two electrode leads. The capacitance between the measuring electrodes with their corresponding leads, and the shield plate and its lead may run in the order of thousands of micro-microfarads. Normal variation in this capacitance has an entirely negligible effect upon the instrument reading.

The balancing capacitor in the instrument measuring system is made with a characteristic to match the relationship between dielectric constant and moisture content of the paper. For low moisture contents, there is a relatively large pen motion for small capacitance change, corresponding to the relatively smaller change of dielectric constant for a given moisture content change. As the capacitance and moisture increase, the pen motion decreases for a given capacitance change, reflecting the larger change in dielectric constant for a given change in moisture content at the high moisture content levels. A rather special adjustment is required for changes in basis weight of the sheet. A 1% change in moisture content obviously results in twice as much change in capacitance for a sheet having twice the basis weight. The adjustment for basis weight must therefore, not only adjust for the change in capacitance due to increased fiber content, but must also adjust the effective sensitivity in proportion to the basis weight of the sheet being measured.

As outlined above, the effectiveness of the circuit and its independence from capacitances to ground depend upon the design of the driving transformer. A close-coupled transformer with maximum coupling between windings is essential. This requires a close-core transformer and limits the frequency of operation, essentially, to the audio-frequency range. A frequency somewhat higher than 5000 cycles might be employed. However, quote satisfactory results have been obtained at this frequency. The null detection circuit in the instrument includes a phase detection network, which results in sensitivity only to potentials resulting from capacitance difference between measuring and rebalancing capacitors. Quadrature unbalance potentials resulting from difference in loss effects in the measuring and rebalance capacitors have no effect at all up to the point where the magnitude is so great that it saturates the amplifier and phase detecting networks. For the normal range of moisture content of paper, the system is unaffected by changes in losses in the paper sheet.

Why Deviations

It must be noted that measurement of moisture is essentially of the deviation type. It is recognized that there is a demand for some instrument which is direct reading in per cent of moisture. While the capacitance measurement and the instruments themselves are sufficiently stable and repeatable to make this seem feasible, the properties of various grades of paper usually run even on a single paper machine introduce so many variables in the capacitance versus moisture relationship that it is decided not to claim moisture measurement in absolute terms.

MICROWAVE MOISTURE MEASUREMENT

The principle upon which this is based states that there is an allowed transition between two rotational energy levels of the water molecule which results in absorption, or induced emission of quanta of electromagnetic energy having quantum energy $h\gamma$ corresponding to a frequency $\gamma = 22{,}235$ Mc/s. Because there are always more molecules in the lower energy level, a net absorption of microwave energy is observed.

The following points cover the principles and the current status of the development:

1. The instrument is being developed jointly by Beloit Iron Works and General Electric Co.
2. Design effort is being directed at on-machine moisture measurement.
3. A natural resonant frequency in the rotational spectrum of the water molecule exists at $22^1/_4$ KMc/s (22,235 Mc/s). There is thus heavy absorption of energy at and in the vicinity of this frequency by water molecules. The corresponding wave length is 1.35 cm.
4. Measurements made on a variety of different papers have shown that the absorption of this frequency in the dry paper is extremely small compared to that in a few percent of water.
5. The measured absorption by water molecules condensed in paper is of the same order of magnitude as reported for liquid water and appears to be several orders of magnitude greater than found for water molecules dispersed as vapor in the atmosphere. The reason for this is not known, but the resonant absorption curve has been found for the water in paper essentially of the same form as reported for the vapor phase.
6. The major development effort is being directed at obtaining a stable and industrially reliable means of bringing the microwave energy into sensing relationship with the paper and of measuring the resulting absorption. For a scanning gage on a paper machine a relatively small area of paper must be sensed.
7. The equipment involved and required in the scanning head is essentially small and light.
8. It is not expected that regular production instruments will be available before 1962.

THE MASONEILAN MOISTURE CONTROL SYSTEM

The Masoneilan moisture control system measures the average moisture content across the entire width of the sheet by utilizing one of the regular paper driers as a "pilot" or "sampling" drier. This pilot drier, which has its own steam admission and condensate removal system, is held at a steam pressure independent of the other driers of the machine or section. The pressure maintained in this drier is usually the average pressure used in the machine or section and is not changed during normal operation. Generally, the pilot drier selected is the second top hot drier from the dry end of the section.

The temperature of the sheet being less than the surface temperature of the pilot drier results in heat transfer from the drier to the sheet. This heat transfer causes steam to condense in the drier at a rate proportional to the difference in temperature between the drier and sheet. The sheet temperature varies proportionally with changes in moisture content, therefore, the change in condensing rate and resulting steam flow to the pilot drier is proportional to the moisture changes. Thus the changes in condensing rate of the pilot drier are utilized as indirect measurements of sheet moisture changes.

The automatic control system varies main drier steam pressure to maintain the moisture content of the sheet at a constant value. A change in the moisture content of the sheet and resultant change in the pilot drier pressure will pneumatically reset the main section pressure controller for a higher or lower steam pressure in the main section as required to establish the correct drying rate.

Operation

Steam pressure to the pilot drier is maintained at the average pressure used in the machine or section by means of non-indicating pressure controller[1] and a air-to-open control valve[2]. A constant pressure is maintained ahead of this pilot drier control valve by means of a pressure controller[3] in combination with a second air-to-open control valve[4] also equipped with a positioner.

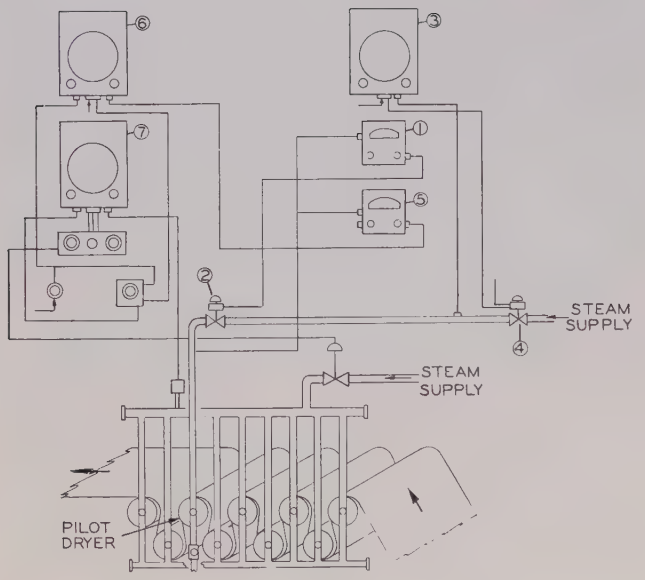

Fig. 17

An increase in the moisture content of the sheet produces a proportional increase in the steam condensing rate of the pilot drier. The resultant decrease in pilot drier pressure actuates the pilot drier pressure controller[1] (set for reverse action) to operate the pilot drier control valve[2] to maintain a constant pressure. At the same time, the pilot drier pressure transmitter[5] (set for reverse action) amplifies and transmits the increased moisture signal to the moisture deviation receiver controller[6]. From this instrument, a proportional amplified signal is sent to the pneumatic set bellows of the main section receiver controller[7] pneumatically shifting the index setting of this instrument. In this way, pressure in the main section is increased to establish the correct drying rate necessary to maintain the desired moisture.

Paper Break Control

When a break occurs, pilot drier pressure tends to rise because of the decreased drying load. The pilot drier pressure controller responds immediately to this pressure increase by transmitting a lower output pressure. This partially closes the control valve to the pilot drier to maintain the pressure within the desired limits. At the sme time, the pilot drier pressure transmitter actuates the moisture deviation receiver controller. Pressure to the pneumatic set bellows of the main section receiver controller is thus changed so that the control point setting is shifted and steam pressure in the main section is maintained at some lower value as determined by the setting of a low pressure index. This low pressure index is a special feature contained in the main section controller to limit the decrease in steam pressure during break conditions. When the sheet is restored, pilot drier pressure tends to decrease, whereupon output pressure from the pilot drier pressure controller operates to increase pressure in the main section and return it to its original value.

(For some applications where excessive machine lags exist, it is necessary to place the system on pressure control).

SUMMARY

In this report, the principles upon which seven commercially available on-the-machine moisture measuring systems function have been explored. There no doubt exist others, and time will certainly result in development of other systems.

With intent, development of drying control features to operate in conjunction with the various mea uring devices was not exploited. The principle that if we can accurately measure, we can control, spells out the reasoning here.

Noteworthy is the fact that absolute moisture measurement as such is not too prevelant. Moisture deviation records, or variation from some zero point is the rule rather than the exception. The variations in sheet additives and machine furnish itself places stumbling blocks in the path of the hoped-for absolute moisture records.

Specific application of any of the aforementioned systems should only be realized after due study normally given other paper mill problems. The nature of each system as it fits operators and maintenance personnel alike is a point not to be overlooked. Under any circumstances, a complete education program in the direction of what is to be accomplished, and how it is to be accomplished, is necessary to the success of any of these systems.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

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Construction Material Successes and Failures in Chlorine Dioxide Manufacturing and Bleach Systems—Project No. 839

R. E. L. WHELESS

A preliminary questionnaire on corrosion problems in the manufacture and use of chlorine dioxide in bleach mills was circulated and the results tabulated. Analysis of this material revealed not only the need for more detailed data in some areas but other areas which apparently need little emphasis. A brief discussion of corrosion experience with major equipment is presented and requests are made for suggestions and comments to be incorporated in the final questionnaire.

In the paper industry, we are every day becoming more aware of how insidious an enemy we face in corrosion, and what a heavy toll it takes of our equipment. This particularily true of pulp bleaching plants, where we not only suffer damage to our equipment, but where rust, scale, and other corrosion products tend to spoil the quality of our product. In an effort to enable the members of our industry to benefit by each others experience in this field, the Pulp Purification Subcommittee of the Corrosion Committee has undertaken to survey the corrosion experience of the industry in pulp bleaching.

Since we feel that a complete questionnaire on all types of bleaching would be too monumental, both to fill out and to tabulate, we propose to work with the individual bleaching agents. Chlorine dioxide, one of the newest as well as probably the most corrosive, was selected as our starting point. In June, 1960, a tentative questionnaire was distributed at the TAPPI Pulp Purification Conference in Chicago. Ten of these completed questionnaires have been received and tabulated. An analysis of the results shows up certain areas in which we need to have more specific data and highlights the equipment which has been subject to the worst corrosion. We propose to prepare, on the basis of this information, a final questionnaire to be mailed out from TAPPI headquarters to all member mills using chlorine dioxide.

If sufficient data can be accumulated, we believe a report of real value can be prepared. Ideally such a report should

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be in the form of recommendations of certain materials for use in specific services. We are not optomistic enough to hope for such success, since it would require information which in many mills will probably not be available, such as actual analysis of the metals used and detailed data on their fabrication. We are certain, however, that the report will make general recommendations and will point out certain precautions which will be of value when we plan new construction to replacements. Later we hope to follow through with studies on corrosion in chlorination, hypochlorite and other bleaching stages.

This report is being presented not only for whatever value it may have in its present form, but in the hope that it will elicit some comments from our members on their corrosion experience in this area and suggestions for material to be included in the final questionnaire and report. The sub-committee will welcome any communication from you on this subject.

The subject of chlorine dioxide manufacture and use in pulp bleaching has been divided into chemical handling, manufacture, and use and equipment in use of each of these areas has been examined.

CHEMICAL HANDLING

Methanol appears to have posed no problems. It seems to be universally stored and handled in mild steel tanks, piping and pumps, estimated to have a life of 10 to 20 years.

Sulfuric Acid used by all reporting mills was 66°Be and has been stored in mild steel tanks with no apparent difficulty. One might expect that the upper walls, which are alternately wetted with acid and exposed to air as the liquid level rises and falls, would eventually show some attack but there were no reports of failure in up to 7 years service. It will be interesting to know the experience of any mills using 60°Be acid.

Piping experience in sulfuric acid handling has been varied. Carbon steel pipe seems to have been satisfactory in seven out of nine reports. Two mills report failure in 3 months to a year. Although the questionnaire did not differentiate between piping for 66°Be acid and dilute acid, we deduce from the reported data that one of these failures was on 66°Be acid and the other on dilute acid. It was noted that both of these mills reported temperature ranges up to 90°F, while all others reported 80°F or lower. Where carbon steel has not been satisfactory, Carpenter 20 seems to have filled the bill.

Pumps for sulfuric acid were all of some resistant material. Reports included 316 stainless steel, carpenter 20, Durimet 20, Hastelloy C, Worthite, Gould-A-loy, and Durimet pumps with ceramic pistons, all apparently satisfactory.

Sodium Chlorate storage tanks appear to have suffered worse from corrosion than piping or pumps. Mild steel seems to have been generally unsatisfactory, failing in from 1 to 3 years time. Personal experience indicates that corrosion is much more rapid in dissolving tanks than storage tanks, and is particularly destructive at the liquid-vapor interface. Two mills have gunnite lined their corroded tanks and report that they are holding up well. One mill has installed a polyester fiberglass lining after $6^1/_2$ years (this tank was $^1/_4$-in. mild steel) but could give no estimate of expected life. Others report 304 stainless steel, 316 stainless steel clad, aluminum type 1 and 2 and the acid-proof brick lined steel in successful use. From sources outside the questionnaire two reports of failure of 316 stainless steel in sodium chlorate services were received recently, one in tank welds the other in a heat exchanger. Both cases were suspected of being at least partially due to stress corrosion.

Mild steel on the other hand seems to have been satisfactory for chlorate piping, although some mills are using PVC or 316 stainless steel.

Pumps of all cast iron or cast iron casings with 316 stainless steel impellers have been in satisfactory use for up to 6 years. Others are using 316 stainless, Alloy 20, Gould-A-loy and Karbate 22.

Molten Sulfur use was reported by two mills, one using mild steel tanks, the other mild steel with $2^1/_2$-in brick lining, both using mild steel pipe.

Sulfur Dioxide used in three mills is handled satisfactorily in mild steel tanks and piping.

In the area of chemical handling, sulfuric acid piping and soldium chlorate dissolving and storage tanks appear to be the two areas of greatest corrosion troubles. Further and more detailed information along these lines will be requested in the final questionnaire.

CHLORINE DIOXIDE MANUFACTURE

Reactors in some of the earliest chlorine dioxide plants were constructed of stoneware, but due to mechanical breakage, these units gave way to brick lined steel with a membrane of some resistant plastic such as PVC, tygon or AR61 with sarancote. These units in turn seem to be giving way to lead or glass-lined steel.

Of the three mills reporting original brick lined reactors, two have replaced them with lead-lined steel, making a total of eight out of ten mills using lead-lined reactors. Of two reports of glass lined reactors one mill has replaced with lead lined and the other reports a repair frequency of 3 months.

Successful lead linings were all of homogeneous chemical lead. Antimony lead was reported as having a maximum life of 1 month. Two mills reported lead lining repairs necessary at the gas outlet, one after 2 years, the other after 5 years use.

The author's experience in replacing packed, brick-lined reactors with water jacketed lead lined steel and consequent elimination of pumps, heat exchangers and circulating lines, has resulted in greatly reduced corrosion and maintenance costs, along with increased plant availability and efficiency.

A wide variety of materials is in use for *Reactor Piping, Instruments Inserts and Nozzles*. These materials have met with varying degrees of success, but because of the great variety and the few mills covered in this report, no definite conclusions can be drawn at this time. The materials in use include, PVC, polyester fiberglass, pyrex, titanium, Hastelloy C, and lead, glass and saran-lined steel. With the exception of titanium and Hastelloy C, gas piping reported included all of the above materials, with the same varying success.

Nine out of ten *Absorbers* reported were of stoneware, tile or brick-lined construction with relatively little trouble reported. The other mill reports use of a PVC lining reinforced with polyester fiberglass. This is a relatively new installation, having been in service for only 8 months.

While corrosion has not been severe in absorbers, ceramic support plate breakage has been a problem and any information on satisfactory substitutes would be of interest.

ClO_2 Solution Storage Tanks have been the source of only minor troubles. Six out of ten tanks are brick or tile lined with a membrance behind the brick. Occasional repointing has been necessary. Two tanks are glass lined, one Tufbond lined and one fiberglass reinforced polyester resin lined. No difficulties are reported with any of these linings, although again the polyester is only about 8 months old.

Seven of our mills are using Saran lined steel for *ClO_2 Solution Piping* for up to 6 years with only an occasional gasket replacement, with the exception of one unit which reports 3 to 5 years life. The others use unplasticized PVC, glass, and fiberglass reinforced polyester resin pipe with no trouble to date.

The data received on *ClO_2 Solution Pumps* is inconclusive, but Durachlor is reported satisfactory for up to six years, Ircamet and Hastelloy C variable, and Alloy 20 unsatisfactory.

CHLORINE DIOXIDE USE

Chlorine Dioxide Mixers lined with Hastelloy C have gener-

ally given 3 to 5 years service, with failures occurring first in the shell lining, while end bells remain intact. The use of titanium nozzles to inject the ClO_2 solution into the center of the pulp stream give promise of increasing the shell life. Cast Hastelloy C rotors have somewhat longer life of 5 or more years. Two mills report titanium lining of the shell with Hastelloy C on end bells and rotor but gave no life expectancy. One user of a 317 stainless lined mixer has renewed the lining approximately every 2 years, while one cast 316 stainless mixer shell was expected to last 15 years, with shaft replacements at 4 to 6 year intervals.

One fiberglass reinforced polyester lining installed in an emergency lasted for eight months.

Chlorine Dioxide Bleaching Towers were all acid-proof brick lined steel with a membrane behind the brick, generally pointed with polyester resin cement. Partial repointing at intervals of 2 to 3 years seems to be all the repair necessary on these towers.

Instrument Inserts, Dilution Nozzles, and Agitators are items about which the questionnaire was not sufficiently specific. In general, however, 316 stainless and 317 stainless are most frequently used with some Hastelloy C, all apparently satisfactory.

Chlorine Dioxide Washing Cylinders with one exception are all of stainless steel, two mills reporting 316 stainless and seven 317 stainless. There were no notations of any severe corrosion in any of these cylinders. One mill has had some pitting in welds and valve castings on 317 in 3 years, and another has had slight etching in the welds in 6 years on 316 stainless. Most of the mills buffer the stock to the washers with caustic soda to PH values ranging from 6 to 8. One mill reports use of a rubber covered washer in this service requiring periodic patching and rebuilding in 7 to 8 years. Stock to this washer is buffered with caustic to a Ph of 8. Information on more cylinders and more detailed data are desirable since repair or replacement of this unit is not only extremely costly but can involve a considerable loss of production time.

Face Wires on all but one of the washers reported were of 317 stainless steel and generally have a life of 3 to 4 years. Two mills report replacement in from 2 to 20 months. Although the operating data are too limited to interpret with accuracy, the shorter life wires were in service at a stock pH of 6.5 and 7.0, while longer lived wires were in service at a pH of 7.0 to 8.0. One 316 stainless face wire has apparently been in service for almost three years.

ClO_2 Washer Vats were all of tile, pointed with a polyester or similar cement with only two mills reporting more than infrequent repointing. One of these two mills has used four different cements, while the other has lined the vat with polyester fiberglass. It was noted that the two latter mills also reported the shortest wire life.

There were almost as many different types of *Washer Hoods* reported as there were washers. In use are fiberglass reinforced polyester, mild steel covered with fiberglass-polyester, aluminum, transite, transite coated with PVC paint, rubber-covered and 316 stainless steel, all apparently giving satisfactory service.

Piping for ClO_2 stock and white water service was divided evenly between 316 and 317 stainless, with one mill reporting an original installation of fiberglass reinforced polyester resin piping on white water, while another is replacing 317 stainless after 5 years with this material. Two mills had failure of white water piping after 4 to 6 months, one using 316 and the other 317 stainless. Both cases were analyzed as being due to improper welding procedures.

No reports of corrosion troubles with *Pumps* in ClO_2 stock or white water service were received. All pumps were of 316 or 317 stainless with the exception of one acid resistant bronze pump in stock service.

No comments in the foregoing material should be considered as a recommendation of any material for a given service over any other material. We have attempted here only a factual report of materials in use in the ten mills reporting. Any accurate analysis has been difficult, because of failure to request certain detailed data in the questionnaire on one hand and failure to report some requested data on the other.

The material collected to date points out the need for more information on specific equipment in chlorine dioxide service. Notable cases being sodium chlorate tanks; ClO_2 mixers; washer cylinders, face and deck wires; and stock and white water piping. When we consider the amount of capital money invested throughout the industry in these items, it is obvious that the time and effort necessary to thoroughly survey corrosion experience in chlorine dioxide manufacture and use will be well spent.

Regional Studies of Digester Corrosion—Progress Report—Project No. 522

H. M. CANAVAN

A short review of the activities of the Corrosion Committee on digester corrosion since the inception of the project in 1950.

In 1950 the Chemical Engineering Committee formed a subcommittee to study digester corrosion. The purpose of the subcommittee was to organize activities for the purpose of determining the cause and remedy for corrosion in sulfate and soda digesters. This study became known as TAPPI Project No. 522.

The subcommittee instituted a regional system of collecting corrosion data on a continuing basis. All data for an individual digester is collected on a single-page form entitled "Mill Report Form." These forms are collected on an annual basis by 11 regional representatives who are appointed from the mill membership on the subcommittee and on a geographical basis.

The regional representatives forward the mill report forms to the Project No. 522 Subcommittee. This subcommittee tabulates the information, evaluates the results and prepares an annual report entitled "Current Status of Alkaline Digester Corrosion as Reported by the Regional Digester Group."

In 1954 this subcommittee was given full committee status as the TAPPI Corrosion Committee. Operating under the jurisdiction of the main Corrosion Commitee, a subcommittee was formed to continue handling Project No. 522.

At the start of this program 80 invitations were sent to mills asking them to participate in the program. Replies were received and 47 mills agreed to participate, while 11 mills were unable to accept and 22 mills did not even reply. The 47 mills that agreed to participate involved 391 digesters.

An annual report was prepared in 1955 based on reports received from 16 mills covering 125 digesters. In 1956, 21 mills reported covering 162 digesters, while in 1957, 30 mills reported covering 229 digesters. In 1958, 30 mills reported covering 197 digesters, and in 1959, 22 mills reported covering 206 digesters. In other words, five annual reports have been prepared and presented.

We are bringing this project to attention because we feel that it is worthwhile and should be kept on a continuing basis. All mills having soda and sulfate digesters are invited to participate in the program.

During this ten-year period the Corrosion Committee was active in studying and eveloping other corrosion information. Corrosion data was accumulated and sent to the Armour Research Foundation, Chicago, Ill., so that a comparative analysis of the data could be made. A report was completed and presented to TAPPI in August, 1953.

H. M. Canavan, Mutual Boiler and Mach. Co., Inc., Waltham, Mass.

Corrosion material was accumulated and evaluated which resulted in the publication in 1954 of TAPPI Monograph Series No. 12 entitled "Inspection of Digesters."

In 1955, five years of the committee's activities were summarized in a paper entitled "Five Years of Investigation of Digester Corrosion by the TAPPI Engineering Subcommittee."

The Corrosion Committee investigated other corrosion problems in pulp and paper mills. In December, 1955, a check-list questionnaire on corrosion was sent to all corporate members of TAPPI. The returned questionnaires were evaluated in a TAPPI Special Report No. 412 entitled "Analysis of Corrosion Questionnaire" prepared in June, 1957.

Other subcommittees have been set up to study various corrosion problems pertaining to the industry.

The project No. 522 Subcommittee is now receiving mill report forms for the year 1960, and the results will be issued in the 1961 Annual Report which is usually presented at the Engineering Conference in October. The general trend in the corrosion rate appears to be increasing, while the main causes are remaining static.

H. M. Canavan

RECENT BOOKS

Advances in Printing Science and Technology—Vol. I. Printing Inks and Color. Proceedings of the Fifth International Conference of Printing Research Institutes. Pergamon Press, New York, N. Y. 352 pages. $12.50.

The proceedings from the Fifth International Conference of Printing Research Institutes are now available as a book entitled "Advances in Printing Science and Technology—Volume I. Printing Inks and Color." The National Printing Ink Research Institute, which hosted the conference at Lehigh University in 1959, announced that the book may be obtained for $12.50 from Pergamon Press, 122 East 55th St., New York 22, N. Y.

The 352-page volume, edited by Dr. W. H. Banks of PATRA, contains 29 technical papers and discussions under the following chapter headings: Influence of Inks, Paper, and Press on Color; Chemistry and Physics of Lithography; Color Control and Separation; Color Measuring Instrumentation; Control of Ink Film Thickness on Presses; Ink Transfer and Rheology; and Ink Colorants.

1956 Bibliographic Survey of Corrosion. NACE Publication No. 60-12. Compiled by Nicole Treves Atlas. Published by National Association of Corrosion Engineers, 1061 M & M Bldg., Houston 2, Tex. 248 pages, 8 1/2 × 11 inches, plastic binding for flat opening. Per copy: nonmembers NACE $27.50; members NACE $22.50.

A collection of 2136 abstracts of technical literature published during 1956 in numerous periodicals over the world related to articles, books, and pamphlets on corrosion and corrosion control. Also included are a small number of abstracts of material published in earlier years not previously included in bibliographies. Abstracts used were selected from those prepared by 31 agencies which have authorized the National Associaton of Corrosion Engineers to use their abstracts.

Abstracts are arranged in the book according to their principal content as classified under the NACE Abstract Filing Index. In this index the literature is classified under eight main headings: General, testing, characteristic corrosion phenomena, corrosive environments, preventing measures, materials of construction, equipment, and industries. Each of these groups is further subdivided.

Each of the subject categories into which the abstracts are grouped is cross-indexed. An extensive subject index is largely supplementary to the cross-indexing, providing access to the data through many metals and alloys by trade names, specific properties and behavior in specific media.

The author index lists 2859 names.

Reference is to page and abstract on the page by number.

An appendix gives information to assist users in obtaining copies of articles in which they are interested.

This is the seventh in a series of NACE bibliographies on corrosion control literature covering the period 1945–56. A total of 22,181 abstracts is included in all volumes.

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(P2002-61)

The Chemistry of Lignin. By F. E. and D. Brauns, New York, 1960, Academic Press. Cloth, 6 × 9, 804 pages. $18.

This book is a supplement to the original book of this title and is a critical review of the literature published from 1949 through 1958 and includes a few papers, mostly from Russia and Japan, that were unavailable for inclusion in the original book. With few exceptions Dr. Brauns, who was formerly a professor on the staff of The Institute of Paper Chemistry, utilizes the same chapter headings as used in the parent volume: evolution of lignin chemistry, distribution of lignin, isolation of lignin, determination, physical properties and the treatments of lignin by alkylation, acylation, nitration, sulfonation, hydrolysis, halogenation, alcoholysis, mercaptolysis, phenolysis, oxidation, and alkali fusion. A new chapter on the linkage of lignin in the plant by J. W. T. Merewether has been added.

Pulp and Paper, Chemistry and Technology, 2nd Ed. Vol. II. By James P. Casey. New York, 1960, Interscience Publishers. 6 × 9, 668 pages and 147 page index. $25.

Volume II of this three-volume set is devoted to papermaking. The original set had two volumes. As the author states any technical book is likely to be out of date 10 years after publication. Mr. Casey indicates his objective to present the technical side of papermaking from a fundamental standpoint. Similar chapter headings appear that were present in the previous edition. Mr. Casey's comments on the reason for producing a revised and greatly enlarged volume are interesting. He points out that the first edition is more out of date than if it had been merely a presentation of technology of the industry. Evidently ideas are changing faster than practice in the paper industry. It is not so much that the old facts are wrong, but that so many new facts have been uncovered that a book acceptable 10 years ago is too far behind the times today.

The great development over the past 10 years has taken place in the areas of pulping, sheet formation, and coating. In sheet formation, particularly, new knowledge is being brought to light so rapidly that it is hard to grasp what effect this will have on future paper machines. In the foreseeable future, paper will continue to be made by separation of fibers from water on a moving wire, but the techniques for doing this, the speeds that will be obtained, and the properties that will be built into the paper of the future is beyond our grasp at the present time. No doubt, the fundamentals are now at hand for the changes that will take place over the next 10 years, just as all the fundamentals were there 10 years ago for the creation of stretchable paper.

Modern Materials 2. Edited by Henry H. Hausner, Consulting Engineer, New York, 1960, Academic Press, Inc. 6 × 9, 413 pages. $12.50.

The second book in a series on modern materials prepared especially for the engineer with broad interests and the specialist who wants information on materials other than those of his own field of specialization. It is interesting to note that the series advisory board include such TAPPI members as E. C. Jahn, Herman Mark, and W. R. Willets and the contributors to the first volume include E. C. Jahn and V. Stannett who deal with polymer modified papers such as wet-strength papers, laminates, plastic coated papers, synthetic fiber papers, and special purpose papers. Other subjects covered in this volume include ceramics, borides, titanium metallurgy, welding materials, and soldering materials.

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Sieve Analysis of Pulpwood Chips*

Revision of Official Standard T 16 m-54, Reclassified as a Tentative Standard†

This method measures the proportions of different-sized aggregates in pulpwood chips by means of sieves. It is useful for controlling various operations in the preparation of chips, for example when to sharpen chipper knives; also for determining the operating efficiency of rechippers, chip breakers, and chip screens.

APPARATUS

1. Sieves. Approximately square sieves, each having not less than 3 sq. ft. of effective screening area and of such depth that, when set in the shaking apparatus, the screen surfaces are not less than $2^3/_4$ in. apart. The screens are round-hole perforated plates conforming (where applicable) to the Standard Specifications for Sieves for Testing Purposes, of the American Society for Testing Materials (*1*). The smoother side of the plates face upwards.

The ASTM sieve specifications applicable to this method are as follows:

(*a*) *Thickness of Plates.* Plates perforated with $^1/_{16}$ to $^1/_8$-in. diam. openings; not less than 0.049 nor more than 0.066 in. thick; plates perforated with $^1/_4$ to $2^1/_2$-in. diam. openings: not less than 0.060 nor more than 0.100 in.

(*b*) *Spacing of Openings.* The openings are spaced, with their centers on equilateral triangles with the widths W, in inches, of metal between adjacent openings for various diameters D, in inches, of opening as follows:

D	$^1/_8$	$^3/_{16}$	$^1/_4$	$^3/_8$	$^1/_2$	$^5/_8$	$^3/_4$	$^7/_8$	1	$1^1/_8$	$1^1/_4$
W	$^3/_{32}$	$^1/_8$	$^1/_8$	$^3/_{16}$	$^3/_{16}$	$^3/_{16}$	$^1/_4$	$^1/_4$	$^3/_8$	$^3/_8$	$^3/_8$

(*c*) *Permissible Variation in Diameter of Openings.* Diameter of openings: $^1/_4$ in. or less, within 5%; over $^1/_4$ in., within 3%.

(*d*) *Permissible Variation in Spacing.* Within 20%.

Select a series of screens according to the nominal (or dominant) size of the chips, as follows:

Normal chip size, in.	*Openings in screens to be used for classifications, in. diam.*				
$^7/_8$	$1^1/_4$	1	$^3/_4$	$^1/_2$	$^1/_4$
$^3/_4$	$1^1/_8$	$^7/_8$	$^5/_8$	$^3/_8$	$^3/_{16}$
$^5/_8$	1	$^3/_4$	$^1/_2$	$^1/_4$	$^1/_8$
$^1/_2$	$^7/_8$	$^5/_8$	$^3/_8$	$^3/_{16}$	$^1/_8$

Provide also a dust tray to catch the undersized material.

2. Screening Mechanism. A metal or wooden frame to hold five screens rigidly and in a level position, and means for shaking them continuously and with sufficient vigor so that the screening, as specified in Procedure, is completed in 7 ± 2 min.

3. Balance. Sensitive to within 0.1% of the weight of the specimen to be tested.

4. Measure. A box or can calibrated to measure a total volume of chips equal to $^1/_4$ cu. ft. per sq. ft. of effective screening area of a screen.

5. Timer. To stop the shaking mechanism automatically or a stop watch.

TEST SPECIMEN

For precise work, air dry the chips before testing. However, for other purposes, if the chips are not air dry, they may be spread on a tray with a fine mesh wire bottom and dried in an oven for 20 to 30 min. at 105 ± 3°C.

By quartering, or by means of a sampler, take from a larger quantity of chips representative of the material to be tested, at least two—and if the standard screening time is not known, at least three—specimens, each having a volume equivalent to $^1/_4$ cu. ft. for each square foot of effective screening area of a single screen; that is, two or more specimens of $^3/_4$ cu. ft. or more. If a trial analysis of one of the specimens indicates that any screen fraction is more than 35% of the total weight, reduce the volume of the next test specimen by 3% for each percent that this fraction is over 35%, provided that the gross volume of the specimen is not less than 0.5 cu. ft.

PROCEDURE

Assemble in the shaker the set of five screens prescribed for the nominal size of chips to be tested, with the screens having the larger holes above those with the smaller holes and with the dust tray at the bottom.

Reserve one specimen for the actual test and use the two other specimens for determining the standard screening time as follows:

Pour one of the specimens over the top screen and start the shaking mechanism. Do not touch the chips while they are being screened.

At the end of the 5 min. stop the shaker, remove the third screen and weigh with its contents. Replace the screen and contents and continue shaking for 20% more time, i.e., another 60 sec., then remove, reweigh

* This method has been accepted by the Standards Committee as a Tentative Standard. Criticisms are invited and should be sent to the Technical Secretary, TAPPI, 360 Lexington Ave., New York 17, N. Y.

† This revision was prepared mainly by E. R. Schafer of the U. S. Forest Products Laboratory, Madison, Wis., in cooperation with other members of the Fibrous Raw Materials Committee.

and replace the third screen and continue shaking for 20% more time, i.e., for another 72 sec., then remove and reweigh. Calculate the percentage change of the net weight of the chips in the third screen at the end of 5 min. during each of the two successive periods. These changes may be positive or negative depending on whether more or fewer chips passed through the second or the third screen respectively, during the two added periods.

The standard screening time is defined as the minimum which when increased by 20%, results in the weight of the chips retained on the third screen (with holes having a diameter of $^1/_8$ in. less than the nominal size of the chips) not increasing nor decreasing by more than 1.5%.

From the changes resulting from screening for the different periods, estimate the approximate standard screening time and verify it by screening the second specimen for the estimated time and for 20% longer, and weighing the chips on the third screen after each period.

Having thus determined the standard screening time, screen the third specimen for that period and weigh the fractions held on each screen and in the dust tray.

Note: It is not necessary to repeat the determination of the standard screening time for additional samples if they are of comparable nominal size and moisture content. However, the determination should be repeated often enough to ensure standard performance.

REPORT

Report the hole diameter of each screen used and the percentage weight of the original specimen retained on that screen and on the dust tray to the nearest 0.5%.

ADDITIONAL INFORMATION

1. This revision modifies the time of screening so that a more definite end point is reached for any type of screening mechanism. Also, dimensions for the screen series for $^1/_2$-in. (nominal) chips have been added.
2. Related Method: German V.Z.u.P.C.I. Markblatt 1/8/56.

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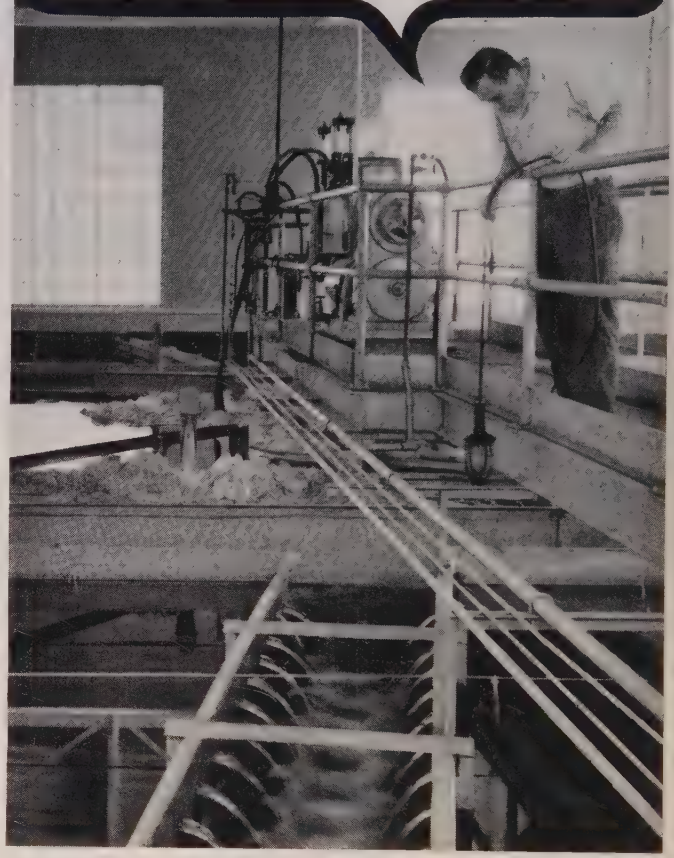
Twelfth
Testing Conference
of the
Technical Association
of the
Pulp and Paper Industry

Queen Elizabeth Hotel
Montreal, Que.
Aug. 15–18, 1961

N-SOL coagulant aid reduces raw water color to low 4/ppm



Consolidated Water Power & Paper Co.

This mill treats 10,000,000 gallons of raw water with color at 90/ppm by using 7/ppm of N-Sol coagulant aid (activated silica)*.

The color of the finished water is a low 4/ppm.

N-Sol and coagulant form a large heavy floc, which enmeshes impurities and suspended matter. The result is clean, clear water.

Besides this better quality water, the silica sol treatment cuts the settling time in half.

Ask for samples of N Silicate and reactant for jar test in your mill.

**N-Sol activated silica is prepared from N sodium silicate (41° Baume; 8.9% Na_2O, 28.7% SiO_2) and a reacting chemical.*

PHILADELPHIA QUARTZ CO.
1141 Public Ledger Bldg., Philadelphia 6, Pa.

PQ SOLUBLE SILICATES

Associates: *Philadelphia Quartz Co. of Calif. Berkeley & Los Angeles, Calif.; Tacoma, Wash.; National Silicates Limited, Toronto & Valleyfield, Canada.*

Trademarks Reg. U.S. Pat. Off.

PQ PLANTS: ANDERSON, IND.; BALTIMORE, MD.; BUFFALO, N.Y.; CHESTER, PA.; JEFFERSONVILLE, IND.; KANSAS CITY, KANS.; RAHWAY, N.J.; ST. LOUIS, MO.; UTICA, ILL.

LOCAL SECTION ACTIVITIES

Pacific

The Pacific Section of TAPPI held its 21st annual Shibley Award contest in Longview, Wash., at the Monticello Hotel, March 21, 1961.

Norval Magnusson, immediate past chairman of the Pacific Section, presided as chairman of the Shibley Award

Head Table—Shibley Award Meeting, Longview, Wash., March 21, 1961. Andrew Broz, Weyerhaeuser Co.; W. W. Clarke, Longview Fibre Co.; Robert Smythe, Secty-Treas. Pacific Section TAPPI; P. T. Dickie, Crown Zellerbach Corp.; C. R. Erickson, Merrill Lynch, Pierce Fenner & Smith, Inc.; Norval Magnusson, Puget Sound Pulp & Timber Co.; and Alec Jackson, Fiber Research (Shibley Award Winner)

program. Three contestants participated and presented the following papers:

1. "Pitch Measurement and Control," by Donald J. Larkin, Development Chemical Engineer, Crown Zellerbach Corp., Camas, Wash.
2. "Simplifying Experimentation by Factorial Design," by John Melcher, III, Chemist, Puget Sound Pulp & Timber Co., Bellingham, Wash.
3. "The Application of the Polarizing Microscope to the Study of Wood and Fiber Structure," by Alec Jackson, Project Chemist, Fiber Research, Seattle, Wash.

Following the presentation of the technical papers was a social hour.

Highlighting the afterdinner program was the presentation of the Shibley Award to Alec Jackson, and acknowledgment to the contestants for their participation in the program. As afterdinner speakers were C. R. Erickson and F. G. Bradshaw, Account Executives, Merrill Lynch, Pierce, Fenner & Smith, Inc., who spoke about the current and past behavior of common stocks and their relation to us today.

Secretary-Treasurer

Simplifying Experimentation by Factorial Design

John Melcher III

The application of factorial design is illustrated in an empirical investigation of the change in viscosity of a spent sulfite liquor with variation in concentration and temperature. The viscosity of the liquor was measured at several concentrations and temperatures selected according to statistical principles, and a second degree polynomial was fitted to the data. This equation expresses the relationship existing between the variables and can be used to calculate the viscosity of the liquor at any concentration and temperature over the range of the investigation.

John Melcher III, Puget Sound Pulp & Timber Co., Bellingham, Wash.

The relationship between interdependent variables can be determined by the tedious classical method of arbitrarily varying one factor at a time but it is more efficient to use the newer factorial design of experiments. In this method experimental conditions are preselected according to certain statistical principles so that a minimum number of observations provide data that can be fitted by an equation relating dependent and independent variables. This paper shows how the method was used to relate viscosity of spent sulfite liquor with changes in temperature and concentration between 30 and 90°C. and 48 and 52% solids.

The factorial design of experiments requires that an equal number of levels be selected for each variable and that these levels be evenly spaced over the range of investigation. For example, in the problem of determining yield in a given process over a pressure range of 60 to 100 p.s.i. with temperature variation of 130 to 140°C., equally spaced levels of pressure and temperature could be 60, 80, and 100 p.s.i. and 130, 135, and 140°C., respectively. The factorial design of the example is a 3^2 type (three levels and two independent variables) requiring measurements at nine combinations of pressure and temperature. The yield is determined at each of these nine conditions and after suitable coding the experimental data are fitted by a second-degree equation such as the following:

$$\text{Yield} = y_0 + b_1P + b_2T + b_{11}P^2 + b_{22}T^2 + b_{12}PT$$

where y_0 is the average of the nine measured yields, and b_1, b_2, etc., are calculated constants, and P and T are coded values of pressure and temperature. Using this equation the yield can be calculated for any given process conditions over the specified range of the investigation.

The problem in hand, relating change in viscosity of spent sulfite liquor to concentration and temperature, was chosen to illustrate a general application of factorial design. The method, with suitable modifications, is applicable to other empirical investigations.

DESIGN OF EXPERIMENT AND PROCEDURE

Design of the Experiment

A 3^2 factorial design was selected to relate the viscosity of spent sulfite liquor to concentration changes in the range 48.0 to 52.0% solids and to temperature variation in the range 30 to 90°C. The levels of concentration and temperature were equally spaced at 48.4, 50.0, and 51.6% total solids and 30, 60, and 90°C., and coded as follows:

$$\text{Coded value} = \frac{\text{uncoded value} - \text{mean level}}{\text{interval between levels}}$$

Thus, for concentration, the coded value,

$$X_c = \frac{C - 50.0}{1.6}$$

Table I. Coded Values of the Independent Variables Corresponding to Equation No. 3

Experimental trial	Independent variable (X_i) x_0	T	C	$T^2 - 2/3$	$C^2 - 2/3$	TC	Dependent variable (Y_i) log η
1	+1	−1	−1	1/3	1/3	+1	2.505
2	+1	0	−1	−2/3	1/3	0	1.751
3	+1	+1	−1	1/3	1/3	−1	1.375
4	+1	−1	0	1/3	−2/3	0	2.781
5	+1	0	0	−2/3	−2/3	0	1.926
6	+1	+1	0	1/3	−2/3	0	1.497
7	+1	−1	+1	1/3	1/3	−1	2.988
8	+1	0	+1	−2/3	1/3	0	2.093
9	+1	+1	+1	1/3	1/3	+1	1.580

and, for temperature,

$$X_T = \frac{T - 60}{30}$$

Appropriate substitution in these expressions, gives coded values of −1, 0, and +1 for the lower, intermediate, and upper level of each variable, respectively.

Experimental Procedure

The viscosity of spent sulfite liquor* was measured at each of the nine required combinations of concentration and temperature using a Brookfield viscometer equipped with the no. 1 spindle and operating at a speed of 6 r.p.m. The samples were placed in tall-form 400 ml. beakers and held in a water bath thermostatically controlled to ±0.5°C. A thin layer of kerosene was placed on top of the liquor to prevent evaporation at elevated temperatures.

Calculations

Fitting the Equation: Calculation of Constants. Using the least squares method the following polynomial was fitted to the data from the nine trials of the experiment:

$$\log \eta = x_0 y_0 + b_1 T + b_2 C + b_{11}(T^2 - 2/3) + b_{22}(C^2 - 2/3) + b_{12} TC \quad (3)$$

where

η = viscosity
C = concentration
T = temperature
b_1, b_2, b_{11}, etc., are calculated constants
x_0 = a constant equal to +1, and
y_0 = the average value of the measured viscosities expressed as the logarithm.

To facilitate treatment of the data, the coded values of the independent variables for each of the nine experiments, together with viscosity expressed as log η, were arranged as in Table I.

In fitting an equation to experimental data by the method of least squares, each constant is calculated by summing the product of the independent and dependent variables for each trial and dividing this value by the sum of the squares of the elements of the independent variable, i.e., $\Sigma X_i Y_i / \Sigma X_i^2$. The constant b_1 was calculated from the elements in the "T" column of Table I, b_2 from the "C" column, b_{11} from the "$T^2 - 2/3$" column, and so on. For example the calculation of b_{11} is as follows:

Table II. Calculated Values of the Constants for Equation No. 3

Constant	Σx_i^2	$\Sigma x_i y_i$	Calculated value of constant $\Sigma x_i y_i / \Sigma x_i^2$
y_0	9	18.496	2.055
b_1	6	− 3.822	−0.637
b_2	6	1.030	0.172
b_{11}	2	0.395	0.197
b_{22}	2	− 0.038	−0.019
b_{12}	4	− 0.278	−0.069

* The spent sulfite liquor was a calcium-base liquor, essentially freed of fermentable sugars and concentrated by evaporation.

Table III. Calculated and Experimental Values of Log of Viscosity

Trial	Experimental log η	Calculated log η
1	2.505	2.510
2	1.751	1.745
3	1.375	1.374
4	2.781	2.771
5	1.926	1.936
6	1.497	1.497
7	2.988	2.993
8	2.093	2.089
9	1.580	1.580

$$\Sigma x_i y_i = 1/3(2.505) - 2/3(1.751) + 1/3(1.375) + 1/3(2.781) - 2/3(1.926) + 1/3(1.497) + 1/3(2.988) - 2/3(2.093) + 1/3(1.580) = 0.395$$

$$\Sigma x_i^2 = (1/3)^2 + (-2/3)^2 + (1/3)^2 + (1/3)^2 + (-2/3)^2 + (1/3)^2 + (1/3)^2 + (-2/3)^2 + (1/3)^2 = 2$$

and $$b_{11} = \frac{\Sigma x_i y_i}{\Sigma x_i^2} = \frac{0.395}{2} = 0.197$$

Values of b_{11} and the other constants calculated in a similar manner are shown in Table II. Substitution of these values into equation (3) yields the following expression:

$$\log \eta = 2.055 - 0.637T + 0.172C + 0.197(T^2 - 2/3) - 0.019(C^2 - 2/3) - 0.069TC \quad (4)$$

Simplification of equation (4) yields the final form of the expression relating viscosity of spent sulfite liquor to concentration and temperature, over the range investigated:

$$\log \eta = 1.936 - 0.637T + 0.172C + 0.197T^2 - 0.019C^2 - 0.069TC \quad (5)$$

Verification of Constants. The accuracy of the constants was checked by comparing values of log η calculated using equation (5) with the values obtained in the experiments.

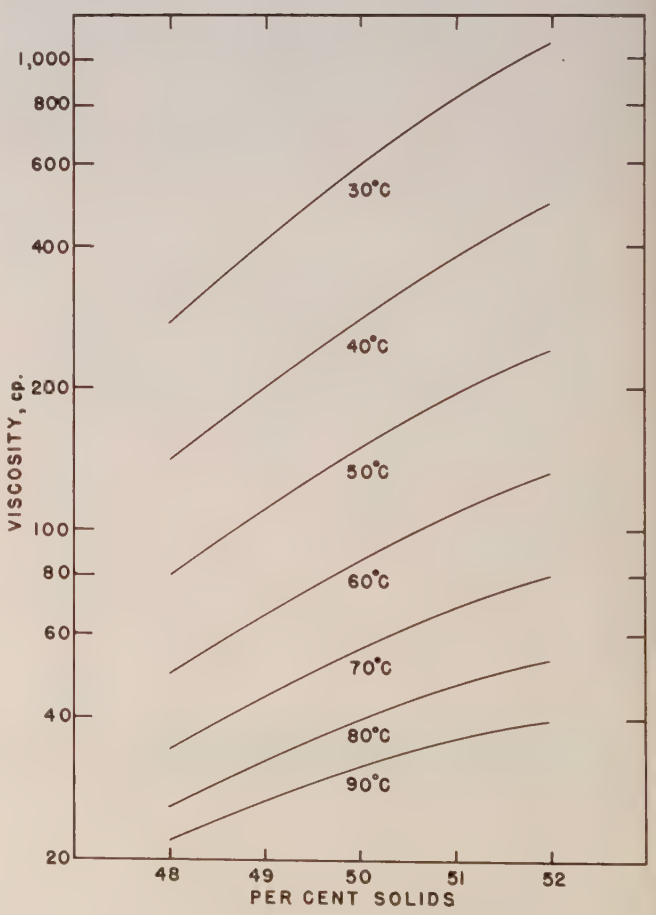


Fig. 1. Variation of viscosity of spent sulfite liquor with changes in concentration and temperature

The resulting comparison presented in Table III shows the two sets of values are in agreement thereby indicating that the constants have been correctly calculated and that the form of the equation chosen fits the data well.

PRESENTATION OF RESULTS

The results of the investigation, presented as a family of curves relating viscosity and concentration at different temperature levels, are shown in Fig. 1. The data used in preparing these curves were calculated by substituting coded values for selected levels of concentration and temperature into equation (5).

DISCUSSION AND CONCLUSIONS

The experiments performed following the 3^2 factorial design have provided data relating the viscosity of spent sulfite liquor to concentration and temperature over the range 48 to 52% solids and 30 to 90°C. It was sufficient to measure viscosity at only three levels of each variable because the range in concentration is small and the relationship between viscosity and temperature is known to be almost linear. The results were fitted by the appropriate equation from which 35 regression points were calculated. Using these values, a family of curves was prepared for convenient interconversion of the variables. The equivalent data from a classically planned investigation would have required individual measurement of viscosity at 20 to 30 combinations of concentration and temperature—a two to threefold increase in experimental effort.

The data from factorial designed experiments need not be presented in graphic form. The equation itself can be used to calculate values of the dependent variable for any given conditions, and inspection of the constants shows the relative effect of each independent variable. The equation can also be differentiated to determine the conditions for which the dependent variable is a maximum or minimum. In contrast with this method, the data obtained in classically planned investigations are not easily represented in equation form and thus does not lend itself to similar mathematical treatment.

These experiments and calculations serve to illustrate the basic concepts of experimental design and demonstrate the versatility and efficiency of the method over the classical procedure.

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A Shibley Award paper presented at a meeting of the Pacific Section of the Technical Association of the Pulp and Paper Industry, held in Longview, Wash., March 21, 1961.

Pitch Measurement and Control

Donald J. Larkin

The problem of depositable pitch has long plagued the pulp and paper industry. Pitch control is best achieved through the use of additives; however, the selection of the proper pitch control agent is often difficult due to the many variables influencing pitch deposition such as furnish, pH, temperature, and mill water composition. This paper presents a method of evaluating pitch control agents and describes the apparatus used in the determinations. The evaluation consists of measuring the amount of depositable pitch after a specified time of agitation at various treatment levels. From the data obtained, the optimum addition level of each additive can be determined and costs compared. Examples of the procedure in operation are shown including its role in the development of a new pitch control agent, Orzan A, a chemical by-product of the ammonia-base sulfite process.

Donald J. Larkin, Development Chemical Engineer, Crown Zellerbach Corp., Camas, Wash.

Pitch deposition has long been a thorn in the side of the pulp and paper industry. This tacky resinous material may coagulate on almost any piece of pulp and paper equipment, wires, felts, press rolls, drier rolls, etc. These deposits result in poor paper quality and reduced production.

The species of wood used has a definite bearing on the gravity of the pitch problem. Woods high in resin content are naturally expected to give trouble; however, the cooking process used is by far the most important factor in causing troublesome pitch. Pulps cooked by the sulfate or soda process rarely give trouble due to the saponification of the resins; these soaps are water soluble and removed during the washing operations. Groundwood sometimes gives pitch trouble but the biggest offender is pulp cooked by the sulfite process. For this reason, the majority of work done in the field of pitch studies has dealt with sulfite pulp.

The mechanism of coagulation and deposition of pitch has been extensively investigated by scientists but no commonly accepted explanation has been presented. Apparently, pulp suspensions form an adsorbed heterogeneous film at the water-air interface. This film contains fatty acids, rosin, lignins, and unsaponifiables (*1*). Investigators are divided as to the cause of deposition, whether the physical properties of the pitch as a whole are to blame or that certain fractions, such as the fatty acids and unsaponifiables, are responsible (*2*).

PITCH MEASUREMENT

The amount of pitchy substance in a given pulp can be determined by the TAPPI Standard T 204 m-46 involving ether and alcohol extractions. However, investigators have shown that this method rarely indicates the tendency of a pulp to give pitch trouble, as pulps with a high extractable resin content may or may not cause problems (*7*).

Therefore, laboratory methods were established by various investigators to simulate conditions in the paper mill for the purpose of accurately measuring pitch depositions. The principle used is the same in all cases: Agitation of the pulp and measurement of the pitch deposited.

Several of the more common methods used are:

1. The immersion of a rotating stainless steel screen in a constant slush flow (*3*).
2. Rotation of a bronze wire screen in a pulp slurry agitated by a Valley beater (*4*).
3. Beating the pulp in a Lampen mill and measuring the pitch deposits on the metal surfaces of the mill (*5*).
4. Agitation of the stock in a specially designed copper or stainless steel container (*6*).

We at Camas have investigated these methods and have selected one which offers good reproducibility as well as speed and simplicity of operation. The method, proposed originally by the Mead Corp. in 1958, was slightly modified by us and utilizes the apparatus as shown in Fig. 1. Our method is as follows:

One hundred and fifty grams of moisture-free pulp at 4%

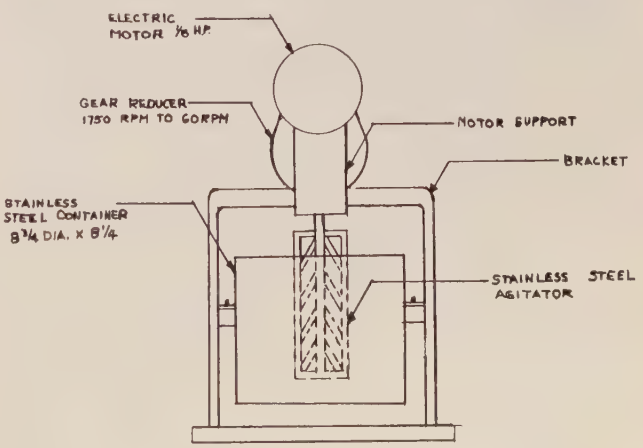
ELECTRIC MOTOR 1/6 H.P.
GEAR REDUCER 1750 RPM TO 60RPM
MOTOR SUPPORT
BRACKET
STAINLESS STEEL CONTAINER 8 1/4 DIA. x 8 1/4
STAINLESS STEEL AGITATOR

Fig. 1. Camas apparatus for measuring depositable pitch

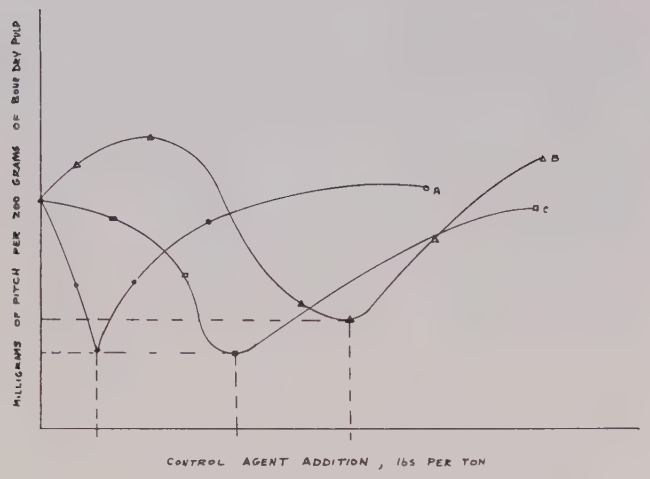

Fig. 2. Typical pitch control agent evaluation

consistency are stirred in a stainless steel container for 2 hr. At the end of this time, the pulp is removed and the container and agitator are rinsed with 250 ml. of ethyl alcohol which dissolves the troublesome pitch. The alcohol is collected in a beaker and evaporated nearly to dryness on a hot plate. When the volume has been reduced to about 10 ml. it is transferred to a tared aluminum dish. The dish is placed in an oven where the remaining alcohol is evaporated. The amount of pitch is reported as milligrams of pitch per 200 g. of moisture-free pulp.

This method is not only useful in the determination of depositable pitch, but has become an excellent tool in the evaluation of materials used for pitch control.

PITCH CONTROL

There are available many types of pitch control agents. Materials such as bentonite, talc, or diatomaceous earth, coat or absorb the individual particles of pitch and prevent them from depositing on the paper machine. Protective colloids, such as starch, animal glue, and gelatin, also by forming films, prevent the coagulation of resinous particles. Certain surface active agents such as sodium hexametaphosphate disperse or emulsify the pitch in the water phase of the suspension (*8*). Cationic surface active agents such as salts of alkyl amines or alkyl ammonium bases cause a fixation of the pitch particles to the pulp fiber.

The deposition of pitch is influenced by many papermaking variables such as pH, temperature, oxidizing and reducing agents, calcium ions, alum, and rosin size. These variables alter the effectiveness of pitch controlling agents requiring an evaluation in each circumstance to determine the satisfactory addition level and agent.

Our procedure for a typical evaluation is as follows.

Using the Camas modification of the Mead mixer method, the amount of depositable pitch is determined for the furnish in question. Pitch control agents are then added in varying amounts to the furnish and the procedure is repeated determining the quantity of pitch deposited in each case. Using the data obtained, a plot with milligrams of pitch per 200 g. of moisture free pulp as the ordinate and control agent addition in pounds per ton as the abscissa is constructed. A typical plot is shown in Fig. 2.

From analysis of the plot, the optimum addition level of each agent is found and costs compared.

In addition to the method's merits as a means of additive evaluation, studies are under way as to the effects of consistency and time of agitation on pitch deposition to determine the optimum point of control agent addition in the paper machine system.

The following incident dramatically illustrates the value of our method.

Preliminary laboratory testing indicated that Orzan A, a pulp and paper chemical by-product manufactured and marketed by Crown Zellerbach, possessed excellent pitch dispersant properties. This material is a mixture of organic chemicals, the two major portions being ammonium lignin sulfonate and sugars (*10*).

Orzan A was evaluated in the laboratory against pitch control agents currently in use in the mill. Both kraft and sulfite furnishes were tested.

Results showed that Orzan A controlled pitch deposition at a much lower cost than the other commercial agents. Based on these results, a mill scale trial was conducted. Laboratory tests were confirmed as Orzan A did an excellent job of pitch control at substantial cost savings.

To date, there are two ways to combat the pitch problem; (1) seasoning the wood or chips and (2) the proper use of additives. Seasoning of the wood or chips in effect oxidizes the pitch to a less tacky state. However, this seasoning time will often run into a period of many months requiring large storage areas. In addition, the amount of wood spoilage due to rot and fungus is increased. In most instances therefore, it is impractical to season as a method of pitch control. On the other hand, pitch control through the proper use of additives is becoming more and more popular and the Camas method provides a valuable tool in evaluating and selecting pitch control additives.

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A Shibley Award paper presented at the meeting of the Pacific Section of TAPPI, held in Longview, Wash., March 21, 1961.

New England Section (Bay District)

A meeting of the Bay District of the New England Section of TAPPI was held at Armand's Beacon Terrace, Framingham, Mass., on March 14, 1961. Approximately one hundred members and guests enjoyed a delicious club sirloin dinner. Chairman John W. Wendell, Jr., conducted a brief business meeting during which the following officers were elected:

Chairman: Albert C. Lamoureux, Dennison Mfg. Co., Framingham, Mass.
Vice-Chairman: David W. Lovering, Arthur D. Little, Inc., Cambridge, Mass.
Treasurer: William P. Stillman, Bird & Son, E. Walpole, Mass.
Secretary: Paul Crane, Oxford Paper Co., Lawrence, Mass.
Executive Committee: John W. Wendell (*ex-officio*), Tileston & Hollingworth, Hyde Park, Mass.; Frank R. Filz, Mead Corp., Leominster, Mass.; Albert Goodrow, Ludlow Papers, Needham Heights, Mass.; John Frankewicz, Oxford Paper Co., Lawrence, Mass.; John Bainbridge, Penick & Ford, Cambridge, Mass.; Edmond C. Kelley, Louis DeJonge Co., Fitchburg, Mass.; Everett Cann, Chas. T. Main Co., Boston, Mass.; John Walsh, A. E. Staley Mfg. Co., Boston, Mass.
Candidate for Chairman of the New England Section: John W. Wendell, Jr., Tileston & Hollingworth Co.

The technical program was introduced by Roger Wiewell, and consisted of two papers on office copy and presented by D. D. Uong and Louis A. Zehner, Jr.

D. D. Uong: Definition of office reproduction differentiating it from "random" or "quasi" office copy methods: office reproduction is defined as an expanded office copy work.

It is a semicommercial printing on systems for production, inventory, and sales. Reproduction copies may range from a dozen to several thousands.

Office reproduction is done an offset press using a master plate. The master plate may be made of paper, plastic, or metal foil. It may be presensitized or direct imaging. More direct image than presensitized plates are being used.

Offset master plates are currently made by six different methods or processes: (1) direct image, (2) white print or diazo, (3) thermo reproduction, (4) silver halide contact, (5) Ektalith, and (6) electrostatic.

Office reproduction has greatly increased consumption of paper. The expenditure on office copy and reproduction work for 1959 is reported to be more than 1 billion dollars.

A demonstration on making offset plate by Xerox under Electrostatic process was shown.

L. A. Zehner, Jr.: In a discussion of the random office copy field (rapid copying of documents where a limited number of copies are required), several key points emerge:

1. This is a true growth industry feeding off a basic evolutionary phenomenon of U. S. business and government—Parkinson's law. While a $200 million industry it has not reached maturity in either a technological or competitive sense; it can be expected to remain dynamic and in a state of flux for some time to come.

2. The paper, coating, and equipment technology is rapidly changing because no known process has approached the criteria for a truly acceptable system; all present processes have significant shortcomings that must be corrected or the whole process will become obsolete.

3. There are still real opportunities for papermakers and converters to participate in this market through the development of improved papers for present processes and in entirely new processes. Participation need not be limited to large integrated companies; the only requirement is superior technology and intelligent merchandising.

David W. Lovering, *Vice-Chairman*

New England Section (Berkshire District)

The March 6 meeting of the Berkshire District of New England Section of TAPPI was held at the Wendell Sherwood Hotel in Pittsfield, Mass.

The problem session held before the general meeting was a continuation of last month's topic of water, fiber recovery, and waste treatment. F. R. Simons of Crane & Co. and Quentin Narum of the Kimberly-Clark New Milford mill sat as a panel along with the discussion leader, Eugene R. Klos of the Peter J. Schweitzer Div., Kimberly-Clark Corp. This type of meeting has proved to be quite popular and was attended by 60 members.

After dinner, Hans Dirzuweit of Huyck Felt Co., and Richard Gillette and J. A. Villalobos of the J. O. Ross Engineering Co., spoke to an audience of 120 people. The J. O. Ross talk concerned new innovations in air drying systems dealing in the main with the high velocity type of drier.

Frederick Klein, vice-chairman of the Berkshire District, opened the meeting by introducing R. G. MacDonald of National TAPPI who reviewed recent TAPPI meetings and events. He was pleased to note that our strength had grown since the District's initial meeting last spring.

Milton J. Gordon, *Assistant Secretary*

Function of Drier Felts in the First Drying Section—Abstract

Hans Dirzuweit

A brief outline of the present use and the history of materials used in drier felts was presented.

The functions of the drier felt in providing support of the sheet, in preventing the formation of cockles, improved heat transfer and in providing the necessary vapor permeability at the dry end was discussed. The absorption of liquid water into the felt and the effect of the increased surface area available for evaporation is considered important.

Experimental data, both from measurements on paper machines and in the laboratory, indicate a significant amount of water is transferred from the sheet to the felt as *liquid* water. The test data showed a strong influence of the capillary structure of the drier felt in this mechanism—the finer structure yielding a greater rate of water removal.

The important point, since the transfer of liquid water in the first drier section is a prime consideration, is that the design of the felt should be such as to capitalize on the longer contact between sheet and felt and the higher temperatures encountered. A fabric with a smooth, fine top surface and a coarse back seems best suited to enhance the mechanism.

To remove sufficient or additional water from the felt, it was suggested that consideration be given to infrared heating, air infringement devices, and the use of perforated rolls to draw or blow heated air through the felt as the use of conventional drying cylinders might not be sufficient.

The significance of an increased rate of drying through use of properly designed felts lies more in the increased production possible where steam drying capacity limits the production rather than in fuel economy. The use of felts on cylinder and roofing machines or other machines where felts are not normally considered necessary was mentioned as a means of increasing speeds.

Hans Dirzuweit, Director, Physical Research & Felt Development, Huyck Felt Co., Rensselaer, N. Y.

New England (Pioneer Valley District)

Pioneer Valley District, New England Section of TAPPI, met on Monday, April 10, 1961, at the Storrowton Tavern, West Springfield, Mass., with 127 members and guests in attendance.

Alex E. Hutton, Jr., Fitchburg Paper Co., Fitchburg, Mass., chairman, introduced Larry Reece, Westfield River Paper Co., Russell, Mass., who, as chairman of the Nominating Committee, reported the following nominations:

Chairman: Alexander E. Hutton, Jr., Fitchburg Paper Co., Fitchburg, Mass.

Vice-Chairman: David T. Habib, Tecnifax Corp., Holyoke, Mass.

Treasurer: William F. Nye, Jr., 65 Ohio Ave., W. Springfield, Mass.

Secretary: Clifford S. Reppe, Hercules Powder Co., Holyoke, Mass.

Executive Committee: F. H. Osborn, C. H. Dexter & Sons, Windsor Locks, Ct.; James Gallatin, Strathmore Paper Co., W. Springfield, Mass.; J. Rex Adams, Old Colony Env. Co., Westfield, Mass.; Burnett Q. Haynes, B. F. Perkins & Sons, Holyoke, Mass.; Edwin A. Bieniek, American Writing Paper Corp., Holyoke, Mass.; Kenneth E. Leger, Westfield River Paper Co., Russell, Mass.; Robert S. Johnston, Ludlow Papers, Inc., Ware, Mass.; E. Whitman Strecker, Esleeck Mfg. Co., Turners Falls, Mass.; J. D. Thomson, Northeastern Paper Sales, Longmeadow, Mass.

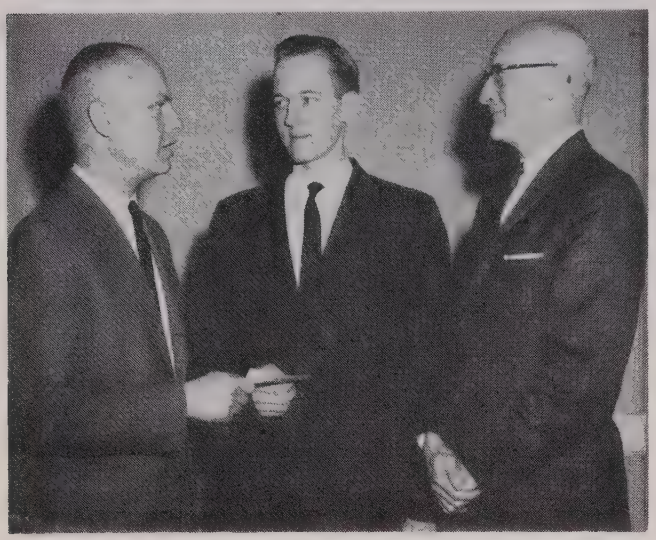
The above nominees were duly elected to serve terms of two years for the officers and one year for the executive committee.

The speaker of the evening, Barton K. Ferce, presented a very interesting talk on "Perception and Observation." This was a unique program involving audience participation. He first developed the fact that various individuals have different powers of observation. He then discussed how one might improve his ability to observe and perceive. He suggested the following points as important in becoming a better observer: (1) be selective, (2) know what to look for, (3) practice observing, (4) keep an open mind, (5) don't be satisfied with a general impression, (6) guard against habit and familiarity, (7) record observations systematically, and (8) develop a check list.

Clifford S. Reppe, *Secretary*

Empire State Section (Central District)

The senior class of the New York State College of Forestry was the guest of Central New York TAPPI on April 7th at the University Club in Syracuse. Mr. Horace Spencer, Director of Research at Knowlton Bros., was guest speaker.



Bert Channer, chairman, Central District; John R. Potter, recipient of the C. E. Libby Award; and F. W. O'Neil, State University of New York College of Forestry

John R. Potter of the senior class was the first recipient of the C. E. Libby award to be given annually to a senior in Pulp & Paper Technology at the College of Forestry. This award is a donation of Empire State Section of TAPPI.

MARIE M. MARTIN, *Secretary*

Gulf States

Aluminum Foil—Laminating, Coating, and Printing

James N. Krause

General manufacturing specifications are given for aluminum foil used in packaging with a brief description of the laminating and coating processes. The various printing processes are discussed and suggestions are made for handling the foil and the benefits and limitations inherent in the various printing processes.

THE production and use of aluminum foil in this country is continuing to grow, having more than doubled since 1952. In 1959, foil producers shipped 212,800,000 lb., over three fourths of which was used in packaging. Today, there is every indication that foil will continue to be a strong and growing factor in packaging. The acceptability which foil has attained may be attributed largely to its versatility, usefulness, and attractiveness, as well as the relative ease with which it has been adapted to existing conversion equipment, particularly in the graphic arts field, for it is in the printed form that foil enjoys its most widespread usage.

In some special instances plain, unsupported aluminum foil is printed on directly, but, generally speaking, it is the laminations of aluminum foil to paper or paperboard which concern the printer. It is our concern to tailor-make these laminations to perform the specific job in question at the least practicable cost.

In the laminating of aluminum foil the most popularly used alloy has a minimum aluminum content of 99.45% and is identified in the industry as "foil purity" alloy. Aluminum foils for laminating range in thickness from just under 0.006 to 0.00025 in.

Foil comes from the rolling mills in a hard temper, having a light film of rolling oils on its surface. Since, for most laminating purposes, the foil must be soft, this hard foil is annealed by heating at temperatures of 800 to 900°F. for 12 to 14 hrs. This process not only makes the foil soft but also removes the surface rolling oils.

Foil in thicknesses up to an including 0.001 in. is generally available with one shiny surface and one dull (or "matte" or "satin") finished surface. This results from the practice of rolling two layers of foil together. The outer surfaces are polished from contact with the rolls and the dull surfaces result from being in contact with one another. Thicknesses heavier than 0.001 in. are shiny on both sides.

There are a number of properties responsible for aluminum foil's usefulness as a packaging and labeling material. The most generally recognized of these, and one of foil's main attributes, is appearance. Its use for point of purchase eye appeal is unexcelled and a wide latitude of decorative effects can be obtained through embossing and coloring. Also, foil is hygienically clean, all of the microorganisms having been destroyed during the annealing operation. Since foil is nontoxic, it may be used in direct contact with many types of foods. It has no taste or odor, thus lending itself to packaging of the most sensitive of foods such as chese or butter.

Soft foil has "dead-fold" characteristics which enable it to be crimped and folded easily, and it will remain completely flexible throughout a range of temperatures far surpassing that required in most packaging applications. The extremely low moisture permeability rate of aluminum foil and aluminum foil laminates is a decisive advantage in packaging. Foil 0.0015 in. thick and over is conceded to have zero permeability, but even in thicknesses as low as 0.00035 in. the transmission rate is negligible. Foil is nonabsorptive to liquids and completely greaseproof. It offers protection against ultraviolet rays and provides a gas barrier in certain types of packaging.

Other important properties of aluminum foil are its heat conductivity and reflectivity. It reflects up to 96% of radiant heat and emits as little as 4%.

In the laminating of aluminum foil combinations of any of the various gages of soft metal and papers from 12-lb. tissue to 30-pt. paper boards may be accomplished. The laminating is done in roll form, which calls for good bending characteristics of the paper stock, particularly in the heavier calipers of board. Another important consideration in selecting a paper or board stock for laminating is surface smoothness.

The most common gage of foil used for laminating is 0.00035 in. in thickness. Foil in this gage will conform quite readily to any surface imperfections on the paper or board stock and the very nature of foil itself tends to magnify these imperfections. For a foil surface that is to be printed the ultimate in smoothness is desired; consequently, great care must be given to the choice of paper or board stocks.

As previously mentioned, the laminating of aluminum foil is done in roll form and is accomplished by unwinding the foil through a series of idlers and passing it over an adhesive applicator roll. This adhesive applicator roll, made of rubber, runs in contact with a steel fountain roll turning in the glue pan. The amount of adhesive applied to the foil is metered by the pressure between these two rolls. The foil then passes over a counter-rotating spreader bar where the film of adhesive is smoothed out and then into combining or nip rolls where it is joined with the paper or board stock. From here, the combined web passes to subsequent coloring, coating, and drying operations.

The adhesives used for foil laminating are generally of three basic types: (1) thermoplastic adhesives which are applied to the foil or paper and dried, laminating is accomplished by passing through hot rolls; (2) hot melt adhesives which are

JAMES N. KRAUSE, Manager of Packaging Development, Anaconda Aluminum Co., Louisville, Ky.

applied in a molten state to the paper or the foil and then combined while still molten, and (3) water-soluble emulsions and dispersed adhesives applied by the same method. It is the third group of adhesives which have enjoyed the most widespread usage in the foil field. These adhesives may be starch, silicate, latex, or polyvinyls. Although foil laminators do not claim to be adhesive experts, they are familiar with the properties of each of these and how they perform; consequently, it is important that the foil laminators have some indication as to the end use so that the correct properties may be built into the lamination.

After the foil is combined with paper or paperboard, the web then passes into the second station on the foil laminator. This station is essentially a gravure head utilizing an etched cylinder for coating. At this station the foil is coated or colored to produce the desired effect or to make it acceptable for one or more types of printing. Here again, in the case of foil stocks to be printed, it is desirable that the foil laminator know the type of printing to be done for different processes require different preparation.

From this coating operation the web then passes through a drying tunnel, where both the adhesive and the coating are dried, and is rewound into roll form at the end of the laminator. It may be asked, "Why is it necessary that the foil be coated for printing?" When foil is laminated to a paper and wound up in roll form, the surface of the foil becomes contaminated. This contamination makes it extremely difficult to achieve adequate ink adhesion to the foil. The exact nature of this contamination is not known but the condition can be prevented by surface treatment of the foil before it comes in contact with the paper.

In the case of gravure or flexographic printing, where the inks used are of a solvent type and need only to have this solvent removed to dry, we use a wash coating or treating which is in reality a microscopically thin film of shellac serving as a basis for ink adhesion. For foil printing by lithography, letterpress, or silkscreen, wherein oil-type inks are used, we coat the surface of the foil with a nitrocellulose or vinyl-type lacquer. This film is applied at the rate of approximately 1 lb. per ream (24 × 36—480). This lacquer film serves a dual purpose. It provides a basis of adhesion and also gives a surface with which the oil type inks may amalgamate to assist in drying.

We have been advised on occasions that various printers have been able to get satisfactory adhesion to uncoated aluminum foil laminations and have seen samples exhibiting excellent adhesion; however, results are not consistent and it is doubtful that any foil laminator will guarantee the printability of an uncoated foil surface.

In addition to the printability of the foil surface, various other factors must be taken into consideration when applying a foil coating insofar as the end use is concerned. The coatings used may be generally classified as decorative, heat sealing, and protective. Each type must have good adhesion to the foil, and, since some may come into contact with food products, it is essential that they be FDA approved and free from odor or taste.

Decorative coatings or printing inks which are to be exposed to sunlight must use colorfast dyes or pigments. Coatings requiring resistance to humidity or moisture must be specifically formulated for this purpose. This was an important factor in developing a coating for matchbook covers where perspiration resistance was of prime importance. Beverage labels in some cases require alcohol resistance and here the use of vinyl lacquers is preferred. There are cases where heat resistance is necessary to perform certain functions of packaging, such as heat seal labeling. All of these examples point out again how important it is that the laminator know the end use of the material in order to insure its proper manufacture.

Heat seal and protective coatings are applied in somewhat heavier films and are generally of a vinyl type, although other coatings are sometimes used, depending upon the specific type of resistance desired. In applications where resistance is to be an important factor, it is best to consider each application as a separate problem and select the coating material and the coating weight best suited to meet the special requirements.

The printing of aluminum foil laminations may be accomplished commercially by the gravure (sheet fed or rotary), flexographic, letterpress, lithographic, and silkscreen processes. The actual printing itself may be carried out very satisfactorily on existing equipment; however, special techniques should be employed to capitalize fully on the design potentials of foil.

Both transparent and opaque colors may be laid on foil. Transparent colors printed directly on foil retain their natural illumination, whereas opaque colors appear much the same as they would on paper stock.

Two colors (two transparent, or one transparent over one opaque) may be combined to create a third color, thus making possible a vivid three color effect with the economics of two-color printing.

Reproduction of natural colors can be achieved using four-color process printing by gravure, letterpress, or lithography. To do this, an opaque white must be laid down first and the process illustration printed over it.

Fine copy should not be printed directly on foil because the high reflectivity of the foil surface may render the copy illegible.

Restraint is necessary in using plain foil areas. Natural foil can be made an integral part of a design if it is skillfully broken up with opaque and transparent color elements. Interest can be focused on a particular part of a design by outlining an opaque area with natural foil. For instance, opaque printed brand names can be pointed up effectively by outlining the letters with natural foil.

Where white and gold are to be printed on the same label, overlapping will produce a buff color; consequently, it is desirable to leave a silver line between the two colors to avoid having this buff edge.

The design of a foil carton can have a very definite effect on the quality and price of the base stock used. If an overall pattern can be developed in the design either by embossing or printing, the smoothness need not be of prime consideration. Smoothness becomes important where large plain areas are present.

It is often desirable and sometimes essential that the finished piece be overcoated to protect the printed surface from scuffing or abrasion. This, then, should be taken into consideration with regard to design insofar as equipment facilities are concerned.

The advantage of any one type of printing over another on foil, as in paper printing, is primarily determined by the size of the run; however, each has its points which should be taken into consideration.

GRAVURE

Gravure involves two procedures; rotogravure, using roll-fed rotary presses printing from cylinders, and sheet-fed gravure, using sheet-fed presses printing from a "strap-on" printing plate. Rotogravure is particularly suited to long continuous runs on big volume packages or labels. Rotogravure, due to the fast drying inks used, has the additional advantage of extremely high speeds without danger of offset or smudge.

On the other hand, gravure cylinders and plates are more expensive than lithographic, letterpress, or flexographic plates and the time required to obtain them may be a deterring factor. Printing on foil by this process should be governed by the same criteria as paper insofar as the economics of run size and printing detail desired are concerned. There are, however, special considerations as to setup and handling.

Care must be taken to avoid pulling uncoated foil webs over stationary bars, or any other surface likely to provide friction, because of the risk of permanently marking the surface of the metal.

Inks used in gravure printing on foil must be fast drying and the solvent lineup should be such that solvents are entirely removed by volatilizing. Type C inks are formulated with the fast drying solvents necessary for foil work and type E inks are particularly suited where residual odor is a factor. Type T inks are also used in foil printing, however, they generally require a special undercoat.

It should be remembered that for labeling applications where labels are removed by caustic solutions, caustic soluble inks should be employed. In all cases consult your ink supplier; although printing inks for foil will sometimes work very well on paper, paper inks will seldom perform satisfactorily on foil.

FLEXOGRAPHY

Flexography is a rotary letterpress operation in which rubber plates are used to print a moving web of stock with inks that dry instantly by evaporation. The main reasons for the popularity of this process are the simplicity and economy of press design and construction as well as the ability to setup and preregister the job off the press, thereby minimizing down time and making short press runs economical.

This process is best suited to printing designs with line detail only and is restricted in the application of these designs on foil only by limitations of the rubber plates for reproducing fine lines and halftones. Anything finer than an 85-line screen usually requires excessive attention to prevent filling in of the pattern.

Flexographic inks for foil printing are usually alcohol base and dry completely by evaporation, thus enabling the same wash coated or treated foil surface to be used as in gravure. The same precautions of running web stock apply as do to gravure, and here again the criteria of run size and quality of printing detail are determining factors.

LITHOGRAPHY

The principle of lithography is based on the simple fact that oil and water do not mix. The printing areas of images are sensitized on the metal plate so as to accept ink, and the areas not to be printed are moistened with water so as to repel inks.

Lithography has long been absent from the field of foil printing; however, there is a large market which can be served by this method of reproduction. Recently, a great deal of interest has been shown in foil lighography and many lithographers throughout the country are accepting and profitably printing commercial jobs on foil.

There are several reasons why lithography on foil is desirable. First, standard litho presses are used, and lithography is by nature practical and economical on small or moderate runs. Secondly, litho on foil is capable of excellent reproduction, to the extent of photographs in full color if necessary. Thirdly, plate costs are moderate and unrelated jobs can be grouped on the same plate. Also, sheet sizes of up to 52 by 76 in. are possible, something outside the scope of gravure and flexography.

Lithography on foil may be accomplished on any weight of laminated stock from 30-lb. paper-backed to heavy weight board stocks. Generally, 60 lb. and up is preferred for sheet fed equipment, whereas web fed can use 30 lb. and up.

It is generally agreed that the use of a nitrocellulose or vinyl type coating is most satisfactory for lithographic reproduction. This type of coating assists in drying of the oil type inks, and, where areas of unprinted foil are exposed in the finished job, there is less tendency to finger mark. Where ink coverage is complete some lithographers have worked satisfactorily on a treated or wash coated foil surface. It is always best to supply a sample of foil stock to the ink manufacturer so that ink adhesion can be checked in advance.

The direction of grain in the paper is not too important, especially in the heavier weights. In using lighter weight stocks it is more desirable to cut the sheets so that the wrap around the rollers conforms to the natural curl tendency of the paper. As in lighographing on paper, the foil sheets should be laid and stored only on flat surfaces.

On standard litho presses, there is no drying equipment and dry offset sprays with special foil inks have been used on most of the commercial jobs to date. There is, however, still some work to be done on the aspect of auxiliary drying in order to insure large volume work at top machine speeds.

In areas to be printed white it is sometimes necessary to apply two passes of color to obtain the desired opacity. In white areas that are to be overprinted it is common practice to allow the white ink to dry overnight. However, recent ink developments may render both of these steps unnecessary in the near future.

One of the principal deterrents to lithographing on foil has been the offsetting of inks onto adjacent paper surfaces during stacking. However, during the past few years a great deal of development work has been done on this, with regard to improvement of the drying and setting rates of inks.

Sheets delivered from a litho press are stacked with the help of lifts. Sheets have been stacked from 500 to 2000 high depending upon the weight of the stock, the type of ink used, the size of the printed area, the thickness of ink film, and the finish on the back of the sheet.

LETTERPRESS

Although letterpress is the oldest form of mechanical printing, it still remains widely used in the packaging field. Its most prominent advantages are strong solids, brilliant colors, relatively easy color control and sharp, clear-cut details. Also, letterpress is probably the most flexible process where changes and corrections are involved.

Letterpress is somewhat limited because of the slow drying characteristics of the inks, and plate wear on long runs. Recently, gloss heat-set inks have been successfully developed for printing on web fed presses, and combinations of heat-set and the usual oil-base inks and other so called quick-set inks have resulted in faster drying inks, helping to get the printed job through the manufacturing process more rapidly.

Whenever possible, use inks full strength so that a very light film will give the desired color with the least tendency to offset. As in lithography, sheets of printed stock should be racked for drying and the same practices of stacking should apply.

SILK SCREEN

Silk screen printing offers many advantages to the packager, but of prime importance to foil printing is the ability to make small runs for tes purposes, or for specialty applications. Some cosmetic manufacturers use silk screen for box wraps printed on foil. A recent rather interesting use of silk screen work was in preparing samples of a can for presentation of the can to a customer, wherein small quantities of various colors were needed as an addition to the basic foil label.

Silk screen has not reached the proportions on foil work that it has in some fields; however, its versatility for point-of-purchase merchandising aids is unexcelled. Several recent developments in silk screen printing have aided its adaptability to foil, notably rapid drying inks and drying equipment to improve production speeds.

Satisfactory printing on foil by any of these processes just mentioned is dependent upon a number of very important factors, such as the consideration of the right type of stock, the correct foil surface and inks, and proper equipment. Your foil laminator and ink suppliers are always available to assist in whatever problems you may incur and appreciate the opportunity to assist you whenever they can. One point to remember in the actual printing: you are not printing

on aluminum foil but rather on an ink-receptive coating on the foil.

Southeastern

The fourth meeting of Southeastern Section of TAPPI took place on March 24–25, 1961, in Augusta, Ga. The record crowd of 211 met at the Richmond Hotel on Friday evening and visited the new Continental Can mill the following morning.

A feature of the evening program was the awarding of prizes in the Section's Annual Technical Paper Contest. The awardees were:

First Prize $100—W. J. Ervin, Brunswick Pulp and Paper Co., "An Impact Meter for Recording Sewer Flow."
Second Prize $75—O. J. Bristow and C. C. Kunz, Union Bag-Camp Paper Corp., "The Problem of Impurities Build-Up in Causticizing Systems at Low Lime Make-up."
Third Prize $50—J. C. McKee, Union Bag-Camp Paper Corp., "The Automatic Sampling and Analytical Screening of Purchased Sawmill Chips."

The other eight participants received certificates.

The Mayor of Augusta, M. A. Beckum, and the manager of the Continental Can mill, W. L. Schnorbach, welcomed the group. Two members of the TAPPI Executive Committee, G. C. Kimble and W. H. Aiken, were introduced.

The first paper was presented by Arthur E. Dentremont, Great Northern Paper Co., "Problems on High-Speed Paper Machines." The startup problems on a high-speed newsprint machine were discussed. These problems included consistency control, freeness for high speed quality, wire mark, pickout, and several others.

The second and third papers were presented by C. W. Ray and B. C. Moore of Continental Can Co. By means of slides, Mr. Ray gave a description of the new mill. Mr. Moore described the startup at the Augusta mill. The talk emphasized the planning and training involved in the startup procedures.

The feature speaker was A. H. Nissan, Rensselaer Polytechnic Institute, "Research Trends in the Paper Industry." The emphasis of the paper was on improving research by broadening our outlook and acquaintances. Our research in the past has been in a straight line. The group was encouraged to find new methods rather than speeding up the old. Getting other technical groups interested in our industry was also encouraged. Dr. Nissan accused the paper industry of isolation. Even though progress has been great, by encouraging new methods; new ideas; finding how other industries develop; even greater accomplishments can be made.

M. Benjamin, *Recording Secretary*

Lake States

One hundred and seventy toured the Neenah Paper Div. of Kimberly-Clark Corp. in the afternoon of April 11, 1961. The dinner and program were held at the Elks Club in Menasha, Wis. Edward J. Jones of The Institute of Paper Chemistry gave a talk on "Strength Evaluation of Pulps."

The C. J. West Award was presented at this meeting. This year we chose an essay type subject, "A Career in the Paper Industry." Robert B. Otto of the Hercules Powder Co. in Milwaukee won the first prize and presented his paper at the meeting. Second place was won by Gary Bezella of the Research Dept. of Marathon, a Div. of American Can, Rothschild, Wis. Third place was won by Harold Willemsen, a chemist in the Technical Dept. at Combined Locks Paper Co., Combined Locks, Wis.

The newly elected officers were also presented at this meeting. Since the last meeting will be held in conjunction with the Green Bay Symposium, we thought it would be better to present the officers at an exclusive meeting of our section.

J. F. Whalen, *Secretary*

A Career in the Paper Industry

Robert B. Otto

Choosing what to do with your life is probably one of the most important decisions you will ever have to make. Having recently received a Degree in Engineering, I know what a difficult and sometimes confusing problem it is to choose a career which may possibly turn out to be one's entire life work. Many things must be carefully considered in order to reach a satisfactory decision. You must evaluate first your own interest, qualifications, and abilities, and then the opportunities offered by the many professions and industries. With these things in mind the young man who is contemplating, or has completed a technical education, would do well to look to America's paper industry for a challenging and rewarding career.

"Why the paper industry?" you might ask. The paper industry is one of the largest, most basic, and essential industries in the United States today. In terms of the value of goods produced it ranks fifth in American industry. Every man, woman, and child in this country consumes over 400 lb. of paper and paper products in a year's time (*1*).

Few people have any real conception of the size and scope of the paper industry. The average person purchases only a small amount of paper as paper itself; more often it is in the form of a magazine, a postage stamp, a towel, a football ticket, or a thousand other essential every-day items which are likely to be taken for granted. Think back about how many items made of paper you have come in contact with today. Imagine how the world would be if all paper goods were to suddenly disappear. You can easily see just how vital and basic paper is to our way of life.

Aside from being one of the largest industries, paper is also one of the fastest growing. In the past 50 years paper production was increased over 1000% while the population has only doubled. Per capita consumption has increased over 400% in the same period (*2*).

The future looks even brighter for paper and paper products. Predictions based upon future population increases and new product development indicate paper production will increase from 60 to 100% in the next 25 years. This is indeed a promising future (*3*).

The paper industry has not always been the industrial giant that it is today. Papermaking was invented in China about the time of Christ. The early papermaking process was a startling discovery, however, it was extremely slow. Each sheet of paper was handmade by dipping a wooden mold into a fiber-water mixture and then draining the water away to form a soggy sheet of paper. Papermaking improved very little until about 1800, when the first continuous papermaking machine was invented. Today our modern, greatly improved paper machines are still based upon the principles used in these early machines. Although papermaking began over 1900 years ago, the industry as we know it today is really just 150 years old (*2*).

To the young man holding a technical degree, the paper industry offers a multitude of career opportunities. With greatly increasing demands for new and improved paper products, competent, technically trained men are needed in all areas of the industry: forest management, research and development, production, and technical sales and service. The paper industry today is going through a technical renaissance. Up until the last quarter century papermaking was considered almost entirely an art, based upon the papermaker's skill and experience. A great portion of papermaking will always be considered an art; however, the need is great today for technical know-how to meet modern-day demands.

Now we have discussed the paper industry, past, present and future, and its need for technically trained men, but what are the specific advantages of a career in paper?" This is

Robert B. Otto, Hercules Powder Co., Milwaukee, Wis.

another excellent question. The paper industry offers today's young men interesting and challenging careers with security and choice of location. Let us look at these points in detail.

One's first visit to a paper mill is usually a surprising and fascinating experience. Few people realize that papermaking is a detailed and complicated process. One can actually see logs, water, and chemicals passing through the many steps to eventually be transformed into a thin sheet of paper. The equipment and machines are large and fast. It is not uncommon to see paper machines the length of a football field produce a 500-mile ribbon of paper in a single day's time.

The visitor to a paper mill may also sense a quality rarely found in modern big industry—the quality of pride and concern the men of the industry have for the making of paper. We spoke before about papermaking being an art, and indeed it is, for much depends upon the skill and experience of the papermaker. His deep pride and feeling for papermaking lends to the industry and air of informality and warmth.

Besides paper being a fascinating industry, it is also a challenging one. Little can be called routine in the making of paper. Every type of paper is an entirely different product, requiring a different set of materials and conditions. Even if all paper were alike, the papermaking process in itself is a complex and detailed operation and the nature of the raw materials adds to the complexity. One would have to look far and wide to find a more challenging industry.

Papermaking offers far greater security than most industries today. Paper, being a basic and essential item to our way of life, is not affected so much by the ups and downs of our economy. History has repeatedly shown the paper industry to withstand far better economic recessions and depressions. Communities which are dependent upon the paper industry usually have a healthy and growing economy.

One advantage not to be overlooked is choice of location. This may not seem very important at first glance; however, many people have strong preferences for certain areas of the country and for certain size communities.

The paper industry in America today is composed of over 1000 pulp and paper mills located in 44 states, including Alaska and Hawaii. Paper communities range in size from small villages to major cities. The industry's dependence upon wood, water, and power limits its location to areas where forests, lakes, and streams are plentiful. These areas usually offer outstanding opportunities for sporting and recreational activities (*4*).

This has been but a brief look at one of America's major industries and its need for competent, technically trained young men. A technical degree is your passport to a promising and rewarding career in the paper industry. The opportunities are many and the future is bright.

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PROCEEDINGS OF THE ELEVENTH TESTING CONFERENCE

Symposium on Relative Humidity and Paper Test Methods

Jointly Sponsored by the Testing Division of the Technical Association of the Pulp and Paper Industry and Committee D-6 on Paper and Paper Products of the American Society for Testing Materials

GRAND RAPIDS, MICH., SEPT. 28, 1960

Wednesday Morning Session—Sept. 28, 1960

The Eleventh Testing Conference of the Technical Association of the Pulp and Paper Industry was convened in the Civic Auditorium, Grand Rapids, Mich., at 9:10 a.m.

T. W. LASHOF: Members and guests, welcome to the symposium on relative humidity and paper test methods.

As you know, the physical properties of paper change appreciably for quite small variations in relative humidity. Present standards for the testing of paper call for the conditioning and testing room to be controlled to 50 ± 2% R.H. and 23 ± 2°C. in temperature. As the speakers in this afternoon's session will discuss, measurement and control of relative humidity in a large test room to these narrow limits is quite a task. Yet some feel that even these limits will result in economically significant differences in the measured properties of the paper.

In order to consider these problems, this symposium on relative humidity and paper test methods was sponsored by the ASTM Committee D-6 on Paper and Paper Products and the TAPPI Testing Division. In planning the symposium we hoped to have four groups of papers to present to you:

1. Effect of Relative Humidity and Temperature on Physical Properties.
2. Measurement of Relative Humidity in a Test Room.
3. Design and Control of Test Room.
4. Economic Questions.

We know that there must be a great deal of information on how much extra it costs a mill to meet a specification when, because of errors in relative humidity in the test room, it gets a falsely low reading in some physical property. However, this information must be in isolated bits since we were unable to obtain a speaker who could put a dollars-and-cents value on a 1% error in relative humidity. Some of you here may have information that you can express in, say, so many dollars per month of production. If so, please bring this out in the discussion, particularly in the discussion of the papers in this morning's session. You will thereby be contributing appreciably to the purpose of this symposium.

We have attending these sessions, and possibly also exhibiting, manufacturers, suppliers, engineers, and contractors who are experts in the field of relative humidity measurement and control. They will undoubtedly contribute to the discussions, especially of the papers to be presented this afternoon. I am sure they also will be very happy to talk over privately with you any problems you have in this field. I also hope that they will learn something from this symposium, particularly as to the true nature of our needs, and this, of course, is the main reason why we have invited them.

The first papers this morning will deal briefly with the possibility of a world standard for conditioning and testing rooms. The other papers will be on the effects of relative humidity on the physical properties of paper.

Your chairman and moderator this morning will be Mr. Henry A. Birdsall, of Bell Telephone Laboratories. Mr. Birdsall is chairman of the ASTM Committee D-6 on Paper and Paper Products. I now give you Mr. Birdsall.

MODERATOR BIRDSALL: Good morning, ladies and gentlemen. It is a pleasure to serve as your moderator for this morning and also bring greetings from the American Society for Testing Materials. ASTM is indeed pleased to have the opportunity to cooperate in the sponsorship of this symposium. Judging from what I have seen of the papers to be presented, it promises to be an extremely important contribution toward advancing the science of paper testing.

The first paper this morning is entitled "Conditioning of Paper Testing Rooms in European Countries." This paper is by Professor Dr. Walter Brecht, who is head of the Institute of Paper Technology at the Technical University of Darmstadt and chairman of the Physical Pulp and Paper Testing Committee of the German Association of the Pulp and Paper Chemists and Engineers.

Unfortunately, Professor Brecht is unable to be present here this morning, but his paper will be read by F. C. Globig, project engineer, Papermaking Department, Research and Development Div. of The Champion Paper and Fibre Co., Hamilton, Ohio.

Dr. Globig received his doctorate from the Technical University of Darmstadt and is a former student and assistant of Professor Brecht. I now give you Dr. Globig.

Conditioning of Paper Testing Rooms in European Countries

W. BRECHT

In America the standard for conditioning of paper testing rooms is 50 + 2% R.H. and 23 + 2°C. The European countries have used for many years another standard conditioning, namely, a relative humidity of 65% and a temperature of 20°C., whereby small differences exist in the tolerance limits. In Germany, for instance, the tolerance limit is ±2% R.H. and ±1°C. It is shown how these standard conditions came about and that in some countries, by careful studies, the advantages and disadvantages of this conditioning standard were examined.

W. BRECHT, Professor Dr.-Ing., Institut für Papierfabrikation Technische Hochschule, Darmstadt, Germany.

At the Eleventh Testing Conference of the Technical Association of the Pulp and Paper Industry it is intended to discuss the influence of relative humidity as related to paper test methods, and at the same time, to investigate the best measuring and control methods for the conditioning atmosphere. The purported reason for examining this special question is the repeatedly expressed opinion that the tolerance limits of the present United States standards of 50 ± 2% R.H. and 23 ± 2°C. are too large.

This may lead to the impression that varied opinions exist concerning the tolerance limits of standard air-conditioning, but not concerning the standard air-conditioning itself, meaning that wherever paper is tested the standard air-conditioning is the same, namely, 50% R.H. at 23°C. This is, however, not the case, and I should like to draw your attention to this fact, merely for its sake, but not to criticize them from the European point of view.

The facts are that, so far, no European country which manufactures paper on any considerable industrial scale employs the United States standard. All countries use as standard for paper testing a relative humidity of 65% and a temperature of 20°C. This applies to the following countries: Austria, France, Great Britain, Poland, Scandinavia (Denmark, Finland, Norway, and Sweden), Switzerland, West- and East-Germany, etc. In tolerance limits, which in Germany are ±2% R.H. and ±1°C., there exist only small differences.

How did this standard of 65% R.H. and 20°C. come into existence? As far as anyone can tell this conditioning standard was first quite generally used for all kinds of material testing by the Staatliche Materialprüfungsamt (National Bureau for Testing Materials) in Berlin. The founding of this bureau in 1884 led to the beginning of scientific paper testing and with it to the objective measurement of paper properties.

The reasons for choosing 65% R.H. and 20°C. may perhaps have been somewhat incidental in that these standards were best suited to the Berlin climate. Since these standards were already generally used by the Staatliche Materialprüfungsamt and all official material testing bureaus, it was only natural that these conditioning standards were also adopted for paper testing. Another reason was that automatically controlled air-conditioning units were not in existence and it was simpler to increase the relative humidity by the existing, rather primitive means, than to decrease it. One may also have been of the opinion that it was better to test paper under conditions moister than those which actually exist when it is used, since the strength of the paper would then be better and on no account worse than that during testing. Later, there may also have been technical and economical reasons which advocated the maintaining of this relatively moist conditioning atmosphere, since in the Middle and South-European countries simple water cooling is not sufficient for attaining conditioning of 50% R.H. and 20°C. so that special cooling systems would be required. These systems are higher in the purchase price as well as much more expensive to operate than simple water cooling.

Today, the situation is as follows. All aforementioned countries use the originally agreed-upon testing air-conditions either as standard or as conventional conditioning. This does, however, not mean that there are no scientific and industrial laboratories which do not use other conditions for special purposes.

The fact remains that the knowledge and experience gained in Europe concerning not only the testing of paper, but also its manufacture and finishing, the whole technological control of operation, as well as commerce, are based upon measurements under these standards. Therefore, all quality standards and terms of supply have, for many decades, complied with these conditioning standards.

This does not, however, imply that this agreed-upon air-conditioning for testing purposes enjoys undivided appreciation. To an increasing extent attention is drawn to the disadvantages. Just now discussions are going on whether the maintaining of traditional conditioning standards, which—as I should like to stress again—are the same as those for the general testing of materials such as textile fibers, can at the present standing of technique and technology still be supported. The fact that more than half of the paper and board production comes entirely under the section entitled "printing," or at least touches upon it, is of special importance. It is known that in places where this kind of paper is processed, the relative humidity is not 65% but only 50 to 55% so that the testing of this kind of paper and board takes place under conditions different from those used in practice.

The changeover to a conditioning standard other than that existing to date would deprive the testing laboratories of any possibility of comparison. In any case, all existing quality control standards and supply terms would have to be discarded and new ones worked out. As it would be important that all European countries again employ the same standard—if possible the American—paper testing in Europe is confronted with a difficult problem. This problem cannot simply be solved by merely blindly adopting the American standard without considering the special structure of European industry which deviates here and there from the American.

The symposium in Grand Rapids is awaited with great interest, as the scientific and technological results issuing from it may be of great importance to the development of the future of European paper testing and serve the end that the differences existing in the fundamental conditions of paper testing on this side of the ocean and beyond be soon eliminated.

Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

Moderator Birdsall: Thank you, Dr. Globig.

Discussion of Dr. Brecht's paper will be deferred until after the second paper because of the related subject matter.

The second paper of this morning's session is not on your printed program. This paper will be delivered by James d'A. Clark, professor of pulp and paper science at the Oregon State College at Corvallis, Ore., and chairman of the TAPPI Standards Committee. We have invited Dr. Clark to give this paper because of his recent trip to Europe. We felt that he could give us some first-hand information of the thoughts on this subject there and his own thoughts on this subject as they apply in the United States.

The subject of Dr. Clark's paper will be "Conditioning for Paper Testing." I present to you Dr. Clark.

Conditioning for Paper Testing

JAMES d'A. CLARK*

The advantages of having the standard conditioning atmosphere for paper testing at 50% R.H. rather than the old TAPPI and present European standard of 65% are: (1) paper is usually made with a moisture content well below that at 65% R.H., (2) 65% is high enough to rust steel instruments and machinery and intensify curling and misregister, (3) 65% is high enough to impair permanently the finish of some high gloss papers, (4) most paper test properties change less about 50% than about 65% R.H. It is believed that as indoor air conditioning becomes more widespread, printers and others will demand a reduction from 65% as they did in the United States when TAPPI reduced its standard to 50% R.H. in 1941. The change appeared to cause no trouble and was quickly accepted. For the sake of International standardization as well as securing material advantages, a plea is made for other countries, also, to consider making a change to 50% R.H. for pulp and paper testing.

James d'A. Clark, Professor of Pulp and Paper Science, Oregon State College, Corvallis, Ore.

* Chairman, TAPPI Standards Committee. A contribution from the Dept. of Chemistry, Oregon State University, Corvallis, Oregon.

It is most unfortunate that in the continent of America, which presently produces and uses about two thirds of the world supply of pulp and paper, a standard of 50% R.H. has become generally adopted; whereas, the rest of the world, which contains far more than two thirds of the world's population, continues with 65%. Sixty-five per cent was inherited from the practice of testing cottons and other textiles, because during the early part of the century the only available laboratories where analytical tests were performed almost invariably dealt also with textiles. For textiles, it was preferred to have the tests made in a high humidity corresponding to that in many textile mills. Also, 65% is about equal to the average outdoor conditions in England, most of Europe, Australia and to that in the United States and Canada.

T 402 m-26, "The Conditioning of Paper and Paperboard," was adopted by TAPPI as a standard with 65% R.H. in July, 1926, but even by that time the writing was on the wall, since 50% R.H. and 70°F. for paper had been adopted by the Joint Committee on Printing of Congress in December, 1923. This action was taken because it was clear that not only was the average indoor humidity in the United States well below 65%, but almost all the leading printers preferred a humidity of about 50% because this was high enough to suppress the development of much static electricity and low enough to suppress dimensional variations and curl.

DISADVANTAGES OF HIGH RELATIVE HUMIDITY

For paper testing, 65% R.H. would seem to be too high because of the following principal reasons:

1. Paper almost invariably comes off the machine with a moisture content well below its equilibrium moisture content at 65% R.H., and, before use, it is seldom moistened up to that level. If it were, curling and wavy edges would be a greater problem.

2. Sixty-five per cent is quite high enough to cause rusting of the steel parts of instruments. This is an annoying and sometimes serious problem in the laboratory, and which, incidentally, if used in a printing plant, would also cause the machinery to rust—especially near the source of the incoming makeup air, which, during the drier months, would have to carry extra moisture.

3. Sixty-five per cent relative humidity is high enough to reduce appreciably the finish of high-gloss papers if raised above the humidity to which they normally would be exposed during printing and use. This loss of finish is irreversible.

4. Between 40 and 50% R.H. most properties of paper change less than at around 65%. Consequently, small fluctuations in the relative humidity of about 50% are not so important as about 65%.

EFFECT OF CHANGES OF RELATIVE HUMIDITY

According to the data of Carson (*1*), who worked with a range of 11 different kinds of paper and avoided the effects of hysteresis, the differences in tests between 50 and 65% R.H. were as follows: On the average, the moisture increased by about 1.2%, the dimensions of the paper also increased about 1.2%, burst decreased about 2.5%, tear increased about 12%, fold increased about 30%, tensile decreased about 10%, and stretch increased 10%.

These figures are significant, but are not much greater than might be expected between different laboratories nominally using the same procedures. As far as past records are concerned, it is an unusual situation where the testing equipment and laboratory procedure have been so well standardized on an absolute basis that the bases for recording the results have not changed more than the cited percentages over the past few years. In any case, most paper and pulp tests are performed directly or indirectly on a basis relative to some other sample or to current use requirements. Both these factors usually change considerably over the years. In addition, with the normal uncertainty of the calibration of the testing instruments, the changes of a few per cent in the "absolute" results in going from 65 to 50% R.H. would not likely cause any greater difficulty than a failure to make calibration tests frequently enough.

Table I. Percentage Moisture Content of Conditioned Papers

Direction of conditioning	*Up to 50% R.H.*	*Down to 50% R.H.*	*Up to 65% R.H.*	*Down to 65% R.H.*
Average for newsprint	9.1	11.0	10.9	13.2
Average for all samples	7.1	8.2	8.5	9.7
Average for blotters	5.9	6.4	6.9	7.9

EFFECT OF HYSTERESIS

Unfortunately, many of those who feel strongly with respect to maintaining their present humidity standards have not paid equal attention to great effect of hysteresis. Morgan and Kress (*2*) have shown that, if a paper is dried down to about 30% R.H. and then conditioned at 65%, as compared to another moistened to 85% R.H. and conditioned at 65%, the differences in the tests are substantial, even when long seasoning intervals are employed.

For example, the average percentage differences were found to be: +1.8 for basis weight, −4.9 for burst, −6.1 for tensile, +13.5 for stretch, +2.9 for tear, and −19 for TAPPI sizing. The maximum differences found were several times greater.

Jarrell (*3*) showed with careful work between 35 and 85% R.H. on several dozen samples of various papers including book, printing, writing, and blotting papers that, as shown in Table I, the effect of hysteresis on moisture content was very marked. Newsprint had the highest equilibrium moisture content, and blotter the least, at all relative humidities.

Since the moisture in paper acts as an effective plasticizer and lubricant for the cellulose, all the effects of changing relative humidity can be explained by considering the effect of changes in the moisture content of the paper. It will be apparent from the table that the equilibrium moisture content of papers dried down to 50% R.H. is about the same as that when moistened up to 65% so that all the physical tests can be expected to be the same under the two conditions of 50 and 65% thus arrived at.

PREVIOUS SURVEYS

In 1940 a TAPPI survey (*4*) of mills showed that of those who had conditioned rooms, 48% used 50% R.H., 35% used 65%, and 17% used other percentages. About a third of those using 65% expressed a desire to change to 50% if the standard was changed, whereas, despite the then existing TAPPI standard of 65%, not a single one of those using 50% R.H. wanted to change back to 65%. In a survey made by APPA (*5*) the same year, half the companies reporting used 50%, and 22% used 65% R.H. The expressed opinion was unanimous that the adoption of 50% would cause no embarrassment or difficulties in connection with the distribution and manufacture of paper products, and it was stated almost unanimously by those using 65% R.H. that if TAPPI changed T 402 m-36 from 65% to 50%, they would conform. Although no similar survey has been made recently by TAPPI, it is safe to say that very few are now not in conformity with the new TAPPI standard of 50% R.H. which was issued in 1941. The point being made here is that in America, where standardization of manufacture and use has perhaps been as far advanced as anywhere else, the change from 65 to 50% R.H. when put into effect, caused no noticeable difficulties.

EFFECT OF TEMPERATURE

If the relative humidity is held constant, the temperature

has a minor effect on the moisture content. However, an increase in temperature causes both thermal expansion of the fibers (comparable to that of metal) and a slight softening of the material, and can have an appreciable effect on some tests.

CONDITIONING EQUIPMENT

Besides the argument that a change from 65 to 50% will badly upset past records, which we see is questionable, another one is that it is said that 65% R.H. is easier to obtain in a laboratory, for example, by the use of coils with natural cold circulating water. With the development and availability of modern household refrigeration, this has become a very minor point, especially if a simple and economic design for a humidity room, such as that suggested by Clark (*6*), is used. The equipment would probably be no more expensive to install and maintain than a large bank of water-cooled coils. Besides, very few laboratories are in a position to have a supply of water cold enough for this purpose during the summer months and in any case, the water needs to be less than 3°C. colder to reach 50% rather than 65% R.H.

CONCLUSIONS

In view of these factors, it seems that if we are to have a world-wide International Standard, it is unrealistic to expect that the manufacturers and users of paper in America would revert to 65% and so dismiss the benefits of the change from 65% to 50% merely for the sake of conformity with a standard favored abroad. This is especially so when, prior to 1941, almost the majority of those interested in paper testing in America refused to conform with the then official TAPPI Standard of 65% R.H. As central heating and air conditioning progresses, it seems safe to predict that within a few score of years, almost all the printing shops and paper users in the world will be operating at an average humidity of well below 65% to avoid the dangers of cockling, curling, misregistering, and the rusting of their equipment. It is also clear that the longer such a change is postponed, the more difficult it will be to change, and, because of the continuing benefits over the centuries to come, the advantages of world standardization from now on would far outweigh the fleeting minor difficulties of making the change from 65% to 50% now.

RECOMMENDATION

The present TAPPI Standard is 50 ± 2% R.H. approached from below 25% R.H., and 73 ± 2°F. As a compromise, it is suggested that for an International Standard for testing of pulp and paper, the conditions be set at 50 ± 1% R.H. approached from below 35% R.H. and 21 ± 1°C. (70 ± 2°F.) for the temperature.

It is believed that these conditions would best suit most practical considerations and, if effected, would remove a powerful psychological block that presently discourages those standardized on one humidity for pulp and paper from close cooperation with those having another. It is hoped it has been demonstrated that there is practically nothing to be lost and substantial benefits to be gained by their world-wide acceptance.

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Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960

MODERATOR BIRDSALL: We now have ten minutes for a discussion of Dr. Brecht's and Dr. Clark's papers. However, before I open the discussion to the floor, I would like to give Dr. Clark and Dr. Globig an opportunity to discuss their respective papers.

DR. GLOBIG: If I can take your remarks, Dr. Clark, as an answer to the paper that I have just read, I would like to state that I know that Professor Brecht is well aware of the facts you mentioned. This paper should, in the first place, inform you here in America about the relative humidity of 65% being used in European paper testing. I am not so sure if all of you were aware of this fact.

This paper did not, by any means, as you will admit, urge the American papermakers to go back to 65% R.H. On the contrary, I think that this paper, as short as it was, elucidated clearly that there is a discussion going on in Europe whether or not a change to 50% R.H. is advisable. I am sure that this fine symposium will help to answer this question. My personal opinion is that sooner or later also in Europe paper will be tested under a relative humidity of 50%.

Please don't underestimate, however, the difficulties involved in such a possible change, especially if different countries with different languages are concerned.

In order to stress this a little, I may remind you of the problem of characterizing the basis weight of paper here in the States and in the English-speaking countries: pounds per ream are still being used, especially by the trade, in spite of the fact that we consider grams per square meter as better.

I do not think that I have any further comments.

MODERATOR BIRDSALL: Dr. Clark, do you wish to comment?

DR. CLARK: Thank you, Dr. Globig.

I don't think that Dr. Brecht is advocating a change at all. What I tried to do in this paper and over on the other side, was to persuade them that there are definite advantages in going to 50% R.H. besides our all being together. I feel that they are receptive and I am very hopeful that they will change.

I might also say from correspondence in Italy, at the present time, they are quite willing to go into the question of adopting 50%. Again, those in Britain who previously opposed changing from 65% today are feeling much more inclined to accept 50. They want to cooperate with us in paper testing, and they realize that as long as they stay with the 65 and we stay with the 50, we are going to remain divergent in developing standard methods. However, if we come together on humidity, we are going to make a good cooperative start.

Comments from Australia indicate that they have 65% there and they feel that because they don't have to have central heating in the winter time, it is not so important to them; also that their humidity generally is higher than ours. Nevertheless, they also are conscious of the discrepancy it leads to in our standard testing methods. Throughout the world today the feeling is such that it would not take much persuasion to get us all on the same basis. This really would be a wonderful accomplishment.

MODERATOR BIRDSALL: Well, we will now invite discussion from the floor on both Professor Brecht's and Dr. Clark's papers.

WARD VERSEPUT (Continental Can Co.): This is not really a question or a discussion, but merely a comment.

There is probably a general impression that this whole question of standardizing across the ocean is somewhat academic. We are all vaguely aware that the conditions for testing used in Europe are different from those we use here, but most of us have never experienced any difficulties because of this difference. I know that I felt this way until I was recently faced with a problem which served to emphasize the need for standardization.

We were to manufacture a product developed by a European affiliate of our company. The specifications had been

nicely worked out, but the units were English, rather than American, so we had to make a translation. Of course, it was fairly simple to convert basis weight from grams per square meter to pounds per thousand square feet (the board makers won't even agree with the papermakers on a unit for basis weight). However, to translate a whole series of physical strength specification from 65% R.H. to 50% R.H. is a much more difficult matter.

We instituted a very small program of testing to see how much difference there was, but as yet we do not have enough data to make an adequate translation.

I just want to point out that this can be a very real problem, and any standardization that can be brought about will be a real help in this kind of situation.

VINCENT N. DE FELICE (St. Croix Paper Co.): Some of the newsprint mill laboratories, which have constant relative humidity-temperature conditions, have found that even 50% is somewhat too high and they are going to 45 and even to 40%. I think we shall do that when we get our laboratory finished.

MODERATOR BIRDSALL: Mr. Gleeson will give us some comments from the Australian viewpoint.

G. L. GLEESON (Australian Paper Manufacturers, Ltd.): I would like to make some comments on behalf of O. O. Nadebaum, chairman of the Testing Committee of the Australian Pulp & Paper Industry Technical Association.

In 1946 he presented a paper titled "Conditions of Relative Humidity and Temperature for Paper Testing in Australia" to an A.P.P.I.T.A. conference. This was published in *A.P.P.I.T.A. Proceedings*, Vol. 3 (1949).

At that time he saw no reason to depart from the conditions of 70°F. and 65% R.H. because these conditions are probably closer to the atmospheric conditions under which paper is stored and used than are the American standards.

A long range view favors the adoption of 50% R.H. and 70°F. for with the extension of air conditioning to more buildings, these values will be nearer those adopted for comfort.

In addition there are the facts previously mentioned, that paper as manufactured is normally on the dry side of equilibrium moisture for 50% R.H. and that dimensional changes are least in the region of 50% R.H.

Thus the long range view in this area would favor the change to 50% R.H.

Whatever arguments may be put forward in any country in favor of 50 or 65% R.H., I should think that they can be outweighed by the case for an international standard. Thank you.

S. M. CHAPMAN (Pulp and Paper Research Institute of Canada) (written comment):

Dr. Brecht's historical references to the reasons for the European use of the 65% R.H. standard have been most interesting. While I agree that 65% humidity is in general easier and less expensive to maintain than 50%, I feel that the American and Canadian standard of 50% R.H. is closer to actual use conditions. Taking for granted the fact that changing from one standard to another will somewhat diminish the usefulness of previously collected data, this is a decision we had to make some 20-odd years ago and we have never regretted the change. If the European countries should decide to use a 50% standard, they would have all our experience and data to fall back on.

PIERO BERSANO (Cartiere Burgo, Torino, Italy) (written comment): On Prof. Brecht's work, I would object to the following: He states that among the reasons in favor of the European standard there is the one to control the paper under more drastic conditions than those in which the paper itself will be used.

I would say that if it is true that the American standard is nearer to the conditions of use, it has to be preferred just for this reason.

Further, as far as the properties of resistance of the paper are concerned, the statement is valid only for the breaking load and the bursting strength. On the contrary, the breaking stretch, the tear, and the folding resistance become worse when there is a decrease of moisture in the paper. Further, following Andersson and Berkyto, *Svensk Papperstidning* 1951-13-444, the area under the stress-strain curve shows a maximum near about 60%.

A world-wide unification of the standard could only be greeted and I am sure that your symposium will contribute to a great extent to the clarification of this aspect of the problem.

On our side, the Italian Section of the TAPPI has entrusted its Testing Methods Committee with the charge of studying the problem, which is the object of your symposium.

As a matter of fact, we do not have in Italy standard methods for paper testing and therefore it is necessary, first of all, to decide at which degree of relative humidity the tests have to be performed.

Most of the Italian laboratories performing tests on papers, and among them all the official laboratories, carry out their tests at 65% R.H. and at a temperature of 20°C. Nevertheless it is a fact that about two thirds of the paper produced in the world are tested in rooms with 50% R.H. For that reason we preferred not to be influenced by the situation pre-existing in Italy and we decided to study the question thoroughly. We examined the more important documents dealing with this matter (especially TAPPI Special Reports Nos. 171, 304, 306, and 307) and asked for the opinion of the leading technical associations. These documents have been translated in Italian and have been distributed to all the members of the Italian Section of TAPPI, together with a digest of the reasons presented in these documents in favor of the 50% and of the 65% R.H. In this way each member will be able to draw his own conclusions and these may be discussed in a meeting we anticipate will be held sometime next fall.

At the end, a survey will be arranged to give all members the possibility to express their preference for either the 50% or the 65% R.H. The results of this survey will be taken as a basis when fixing the percentage of relative humidity for an Italian standard for paper testing.

MODERATOR BIRDSALL: Now then, are there any other discussants of the first two papers? We will then go on with the program.

The third paper on this morning's program is entitled, "The Effect of Relative Humidity on the Stress-Strain Properties of Multiwall Paper." The paper has been written by Miss G. A. Bernier and W. E. Carlson of the St. Regis Paper Co., Carthage, New York.

The paper will be delivered by Mr. Carlson, who is manager of research of the St. Regis Paper Co. He received his B.S. in Chemical Engineering at Iowa State College, his M.S. in Chemistry at The Institute of Paper Chemistry and has presented papers in statistical sessions of TAPPI in 1956, 1957, an 1960. I am happy to present to you Mr. Carlson.

The Effect of Relative Humidity on the Stress-Strain Properties of Multiwall Paper

G. A. BERNIER and W. E. CARLSON

In usage, multiwall bag materials are subjected to loading conditions which are not necessarily of rupture proportions. In addition to this, they are subjected to a wide range of humidity, temperature, and time conditions. In the past, traditional tests have been tensile, stretch, and tearing resistance. With the advent of the new extensible papers, such tests as tensile-energy-absorption, Frag bursting energy, and impulse testing have appeared. While these test methods serve a useful control or screening function, they yield little basic information as to the mechanism or history of failure in multiwall materials.

G. A. BERNIER, Mathematician, and W. E. CARLSON, Manager of Central Research, St. Regis Paper Co., Carthage, N. Y.

Therefore, it is desirable to develop an acceptable test method which will explain the effects of time, temperature, and humidity and previous history on the field performance of all types of multiwall materials. The current study was undertaken to determine humidity's effect on some of the stress-strain properties of a wide range of types of multiwall bag materials including the conventional flat kraft, compressively shrunk extensible paper, creped and embossed extensible paper, microcrepe, and a viscose fiber web bonded with a hydrophobic binder. As was expected, tensile strength decreased with increasing humidity, while stretch and tearing resistance increased. Recovery properties of the materials tested exhibited gross differences, indicating that the method of manufacturing exerts an appreciable influence on the stress-strain properties of the materials. Recovery properties of the kraft materials tested decreased with increasing humidity while those of the viscose web bonded with the hydrophobic binder increased, indicating that failure at high humidities is primarily due to bond failure. The apparent modulus of elasticity, which is related to the rigidity of the material, decreased with increased humidity. The flat kraft material was much more stiff than the extensible papers. A possible working mechanism of failure has been suggested by the effect of humidity changes on recovery and rigidity characteristics in corroboration with field performance of multiwall sacks and the stress-strain characteristics of these materials at high rates of elongation.

In usage, multiwall bags are subjected to two basically different types of loading conditions. In one case, a definite strain is developed which generates stresses, as in the bag making and printing operations. In the other case, an application of a stress gives rise to a strain, as in the handling and transportation of the filled bags. In addition to this, the bags are subjected to a wide range of humidity and temperatures.

In the past, traditional tests for multiwall bag materials have been tensile, stretch, and tearing resistance. With the advent of the new extensible papers, such tests as tensile-energy-absorption, Frag bursting energy, and impulse testing have been used to evaluate the materials. While these tests serve a useful purpose in maintaining the quality and uniformity of production, and somehow relating to the ultimate strength of the materials, they yield little basic information as to the mechanism or history of failure in multiwall materials.

Therefore, it seems desirable to develop an acceptable test method for multiwall materials which satisfies three basic conditions:

1. It should explain the reasons for good performance of all types of materials.
2. It should explain the causes of poor performance.
3. It should explain the effects of humidity, temperature, time, and previous loading history on the performance characteristics of all types of materials.

PROCEDURE

It is a well-known fact that paper is very sensitive to moisture changes, therefore, a study was initiated to determine the effect of humidity on the stress-strain properties of multiwall bag materials. Materials tested included the conventional flat kraft, two types of the new extensible papers (compressively shrunk extensible paper and creped embossed paper), microcrepe paper and a bonded fabric made of viscose fibers bonded with a hydrophobic binder. Specimens were conditioned for 48 hr. at the low humidity and testing was carried out over a range of humidity from 20 to 90% R.H. When specimens were conditioned for 48 hr. at the high humidity and tested over a range of 80 to 20% R.H., hysteresis was noted. Testing was done at 73° ± 2°F. All testing for stress-strain properties was done in a

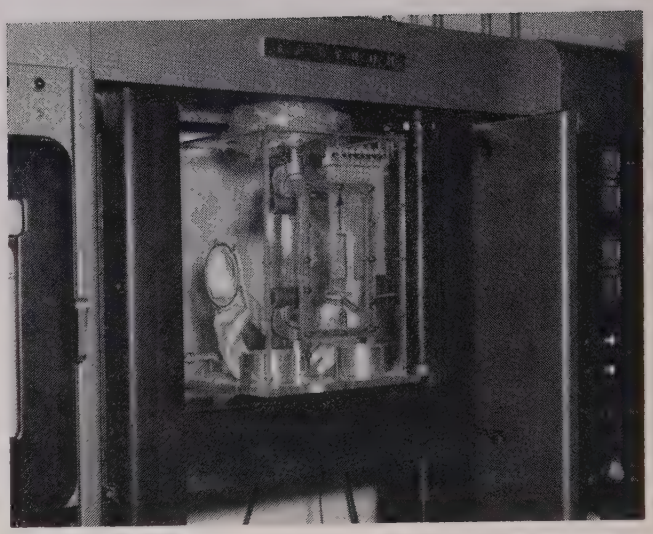

Fig. 1. Cabinet mounted on Instron tensile tester

plexiglass cabinet mounted between the drive screws of a floor model Instron tensile tester. Testing rate was 0.5 in. per min. with a 5-in. gage length. Humidities were varied by the use of the following chemicals:

1. 20% Relative humidity—dry calcium chloride.
2. 35% Relative humidity—saturated solution of magnesium chloride.
3. 50% Relative humidity—standard test room conditions.
4. 65% Relative humidity—saturated solution of sodium nitrite.
5. 80% Relative humidity—saturated solution of potassium chromate.
6. 90% Relative humidity—saturated solution of calcium sulfate.

Before discussing the results of our study, some of the terms and principles should be defined. When a specimen is subjected to an extension in a tensile testing machine such as an Instron, a load is transmitted to a sensing element. By plotting the change in load with changing extension, a typical stress-strain curve results (Fig. 2).

From this curve, the following information can be obtained:

1. *Tensile Strength*—the ability of the material to carry a load, defined as the maximum load carried by the material prior to rupture.
2. *Ultimate Elongation (Stretch)*—the ability of the material to undergo deformation, defined as the elongation of the specimen at the rupture point.
3. *Tensile-Energy-Absorption (T.E.A.)*—the ability of the material to endure large permanent deformations, defined as the area under the curve.

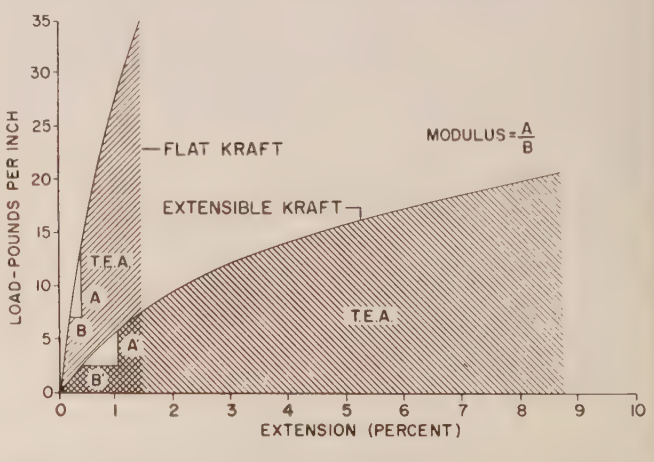

Fig. 2. Typical stress-strain curves, 50% relative humidity, machine direction

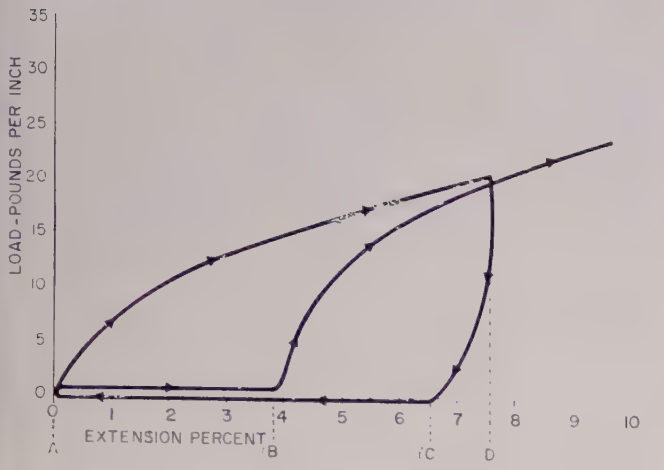

Fig. 3. Elements of total extension, extensible kraft machine direction, 50% relative humidity

4. *Apparent Modulus of Elasticity*—the ability of the material to carry a load linearly related to deformation, measured as the slope of the Hookean (initial straight line) portion of the stress curve corrected for per cent (100) and cross-sectional area (A) as follows: (slope) (100/A).

PROPOSED MECHANISM OF PAPER BEHAVIOR

By title this study is a report on the effect of relative humidity on sack paper properties. Actually at room temperature, the important variable probably is web moisture and the method of conditioning has an effect on web moisture because of the well-known moisture-relative humidity hysteresis curves. In the plots that follow, per cent relative humidity in effect designates a point on the adsorption portion of the hysteresis curve.

Only machine direction properties are considered in this study. Present manufacturing methods have their greatest effect on the machine direction. As an example, note the difference in extension of natural and extensible kraft sack papers.

It is possible to partition the elements of the total extension of the specimen. If, instead of extending the specimen to rupture, the test is stopped short of the rupture point, relaxation of the load is observed. If the tester is reversed, the specimen immediately recovers a portion of the total extension. When the jaws of the tester are returned to their original position, the specimen droops because of permanent deformation. If the test is repeated after 30 min. another stress-strain curve, which does not retrace the original curve, is generated (Fig. 3). The portion of the extension labeled AB is defined as the plastic stretch since it does not recover with time. That portion labeled BC is the delayed elastic

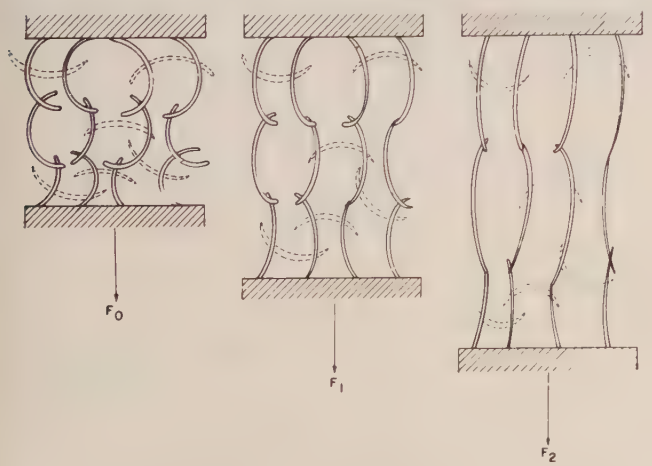

Fig. 4. Extension of a fibrous network, no failures

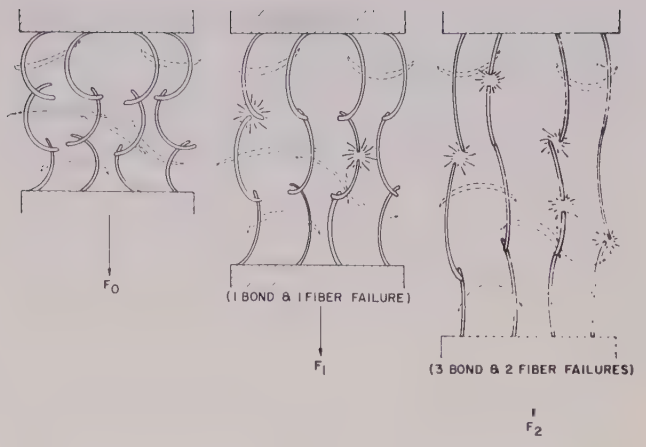

Fig. 5. Extension of a fibrous network, fiber and bond failures

extension. The portion labeled CD is defined as the instantaneous recoverable extension (IRE). This portion (IRE) was found to positively correlate very well with elevator bag drops for natural and extensible kraft papers and synthetic papers in the form of sewn bags provided that failure was the result of body breakage at 50% R.H. Instantaneous recoverable extension values reported here are the amount of extension recovered after the 5-in. specimen has been extended at a rate of 0.5 in. per min. to 85% of its total extension, held there for 5 min., and the jaws returned to their original position at a rate of 0.5 in. per min.

Strength of paper is the result of two factors—the strength of the individual fibers and the strength of the bonds between the fibers. Van den Akker (*1*) points out that the strength of paper is primarily due to the strength of the fiber-to-fiber bonds with failure initiating in the bonds rather than in the fibers. This is substantiated by the fact that the breaking length of paper is less than that of the fibers making up the paper. Rance (*2*) points out that the bonds of a specimen subjected to mechanical stretching begin to break up at once. Simplified diagrams can be drawn to show that an extended fibrous network will tend to recover its original dimensions if there are no failures of the fibers or the bonds between the fibers. If no failures occur (Fig. 4), an increase in the amount of recovery would be expected with an increase in the extension. However, if the fibers or bonds fail (Fig. 5) the broken fibers relax, and that segment has no tendency to recover. Therefore, the degree of recovery by a specimen subjected to increasing amounts of extension will be reduced because of the mechanism of fiber and bond destruction.

THE EFFECT OF HUMIDITY ON ELASTIC PROPERTIES

When extensible and flat kraft specimens were subjected to

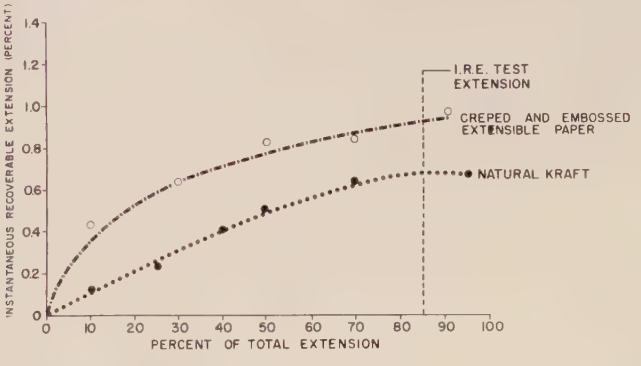

Fig. 6. Effect of amount of strain on instantaneous recoverable extension of bag papers, machine direction, 50% R.H.

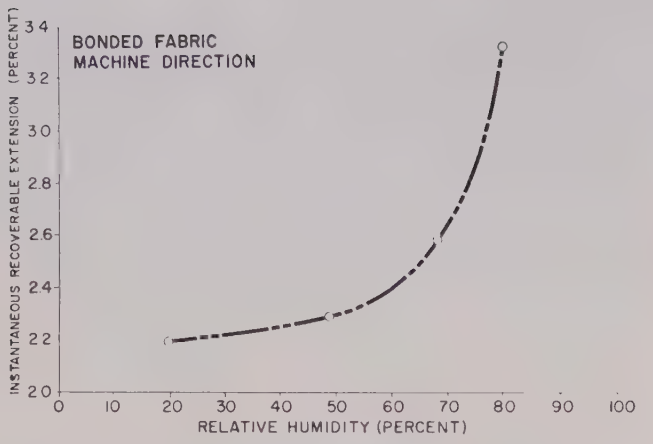

Fig. 7. Effect of relative humidity on instantaneous recoverable extension

varying amounts of extension and the recovery properties measured, the following diagram resulted. This diagram indicates that at 50% R.H., the recovery properties of the extensible and the flat kraft level off when the specimen has been extended in the range between 70 and 90% of its total extension. This would imply that the recovery properties of the more extended fibers are offset by the loss in recovery properties caused by fiber and bond failure (Fig. 6).

It is well known that cellulosic fibers such as viscose become more elastic as humidity rises. Therefore, the recovery properties of the web could be expected to increase with humidity, providing that the humidity does not affect the bonding structure of the web. This was found to be true in the case of the viscose fibrous web in which a synthetic hydrophobic binder was used.

Figure 7 shows a 50% increase in recovery properties with a change in humidity from 20 to 85%. This is in accord with the increase in elasticity of the viscose fiber. In the case of the natural kraft, it was found that the IRE reached the maximum at 40 to 65% R.H. and decreased slightly at drier and more moist conditions. In the case of the compressively shrunk extensible paper, the IRE at low humidities was high, but a decrease of 50% in IRE was noted at high humidities. In the case of the creped-embossed extensible paper, a decrease of 20% in IRE was noted from the low to the high humidities (Fig. 8). The effect of varying humidity caused the IRE's of the viscose web, the flat kraft sheet, and the extensible papers to behave in grossly different ways.

However, the moisture content of all specimens was nearly the same at a specific humidity (Fig. 9) indicating that the different fibers were not too unlike in their overall structure. This is particularly true in the case of extensible and flat kraft sheets.

Therefore, the behavior differences at high humidity must be assumed to be caused by humidity's effect on the bonds and network continuity. In the case of the viscose fiber web, the use of hydrophobic binder, which was not affected

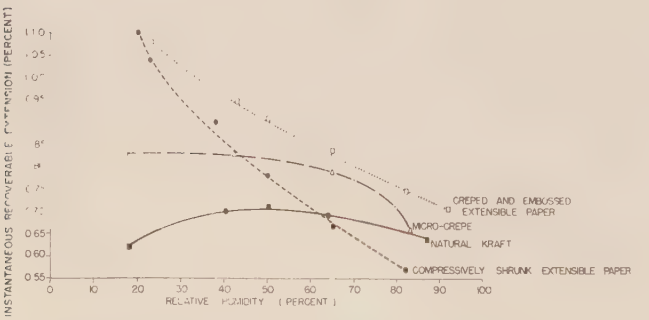

Fig. 8. Effect of relative humidity on instantaneous recoverable extension of IRE bag papers, machine direction

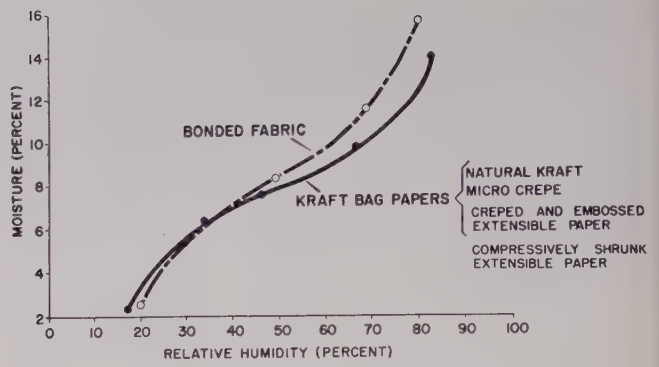

Fig. 9. Effect of relative humidity on moisture content of bag papers

by moisture, allowed the elastic properties of fibers to contribute to the recovery properties of the material. In the kraft sheets, moisture must have affected the bonding probably causing the bonds to fail before the effect of the expected elasticity increase of the fibers could contribute to the recovery properties of the web. The difference in magnitude of the recovery properties of the various kraft sheets is apparently due to the difference in manufacturing methods used in forming the sheets.

EFFECT OF HUMIDITY ON OTHER SHEET PROPERTIES

As was expected, tensile strength decreased. The tensile strength of the bonded fabric tested ranged from 12 lb. at low humidity to 6 lb. at the high humidity. Stretch increased with increasing humidity in all cases (Figs. 10 and 11).

The tensile-energy-absorption plots (Fig. 12) for the more stretchable webs generally pass through a maximum at different humidities. Because T.E.A. is the integrated product of tensile and stretch, both of which are affected differently by humidity (Figs. 10 and 11) and the shape of their stress-strain curves changes with humidity, as indicated by change in apparent modulus of elasticity (Fig. 13), a linear relation between T.E.A. and relative humidity would not be expected.

Since the modulus of elasticity can be readily determined from the stress-strain curves and is related to the rigidity of the material, a study was made to determine the effect of humidity on this property (Fig. 13).

All types of materials became more stiff at lower humidities, with the flat kraft having a greater modulus than the extensible materials or the bonded fabric. Tearing resistance generally increased with increasing humidity for all types of materials as was expected (Fig. 14).

As humidity increased, the apparent modulus of elasticity decreased and the work required to propagate a tear increased. This is in accord with the present theories that as a

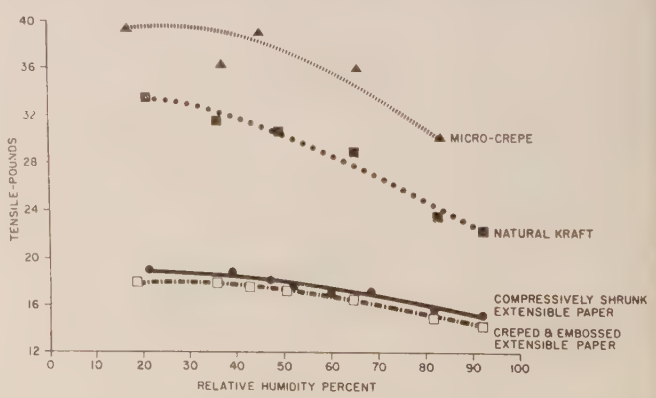

Fig. 10. Effect of relative humidity on tensile strength of bag papers, machine direction

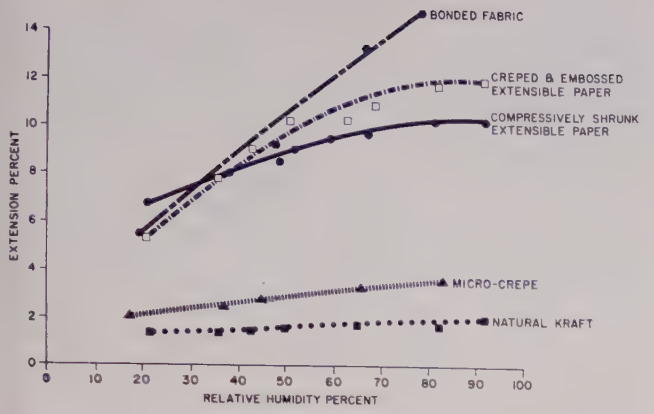

Fig. 11. Effect of relative humidity on percent extension of bag papers, machine direction

material becomes less rigid, stress in the rupture zone becomes more diffused thereby increasing work of rupture; or that a greater percentage of fibers are pulled apart rather than fractured, thereby increasing the work of rupture (*3*).

SACK FAILURE

A study of the elastic behavior of multiwall papers at very high rates of extension was made at the Fabric Research Laboratories. Stress-strain diagrams obtained at these high rates of extension (200,000% per min.) were of the same general shape and same total stretch as those obtained at conventional rates of testing (10% per min.). The specimens tested at these high rates of extension exhibited plastic stretch and after testing were permanently deformed or extended. When an extensible paper bag was dropped at 50% R.H. to failure and material adjacent to the failure zone tested, it was found to have retained its plastic stretch. This appears to be substantiated by the fact that the bags after dropping only increased about 1% or less in length. Since the bag paper has not been appreciably extended in this plastic region—although paper specimens do extend in the plastic region at high rates of loading—the extensible paper bag must fail by a different mechanism than is true of a strip subjected to a very rapid extension or shock. In order to examine this apparent paradox (that paper stretches at high rates of loading, but paper sacks dropped to failure have not been stretched), a notch or tear was initiated perpendicular to the axis of extension and the specimens tested in the conventional manner. The stress-strain curve of the wounded specimens is very similar to the linear portion of the conventional stress-strain curve. The curves of these wounded specimens do not exhibit any typical plastic stretch at low humidity and humidity has a great effect on these diagrams. Taylor (*4*) reports that in a test of this type on cotton fabric, the material fails by the breaking of fibers one at a time or in very small groups in the neighborhood of the breaking fibers

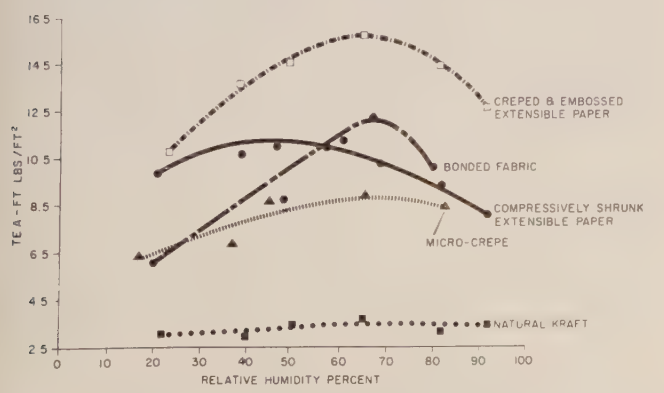

Fig. 12. Effect of relative humidity on tensile energy absorption of bag papers, machine direction

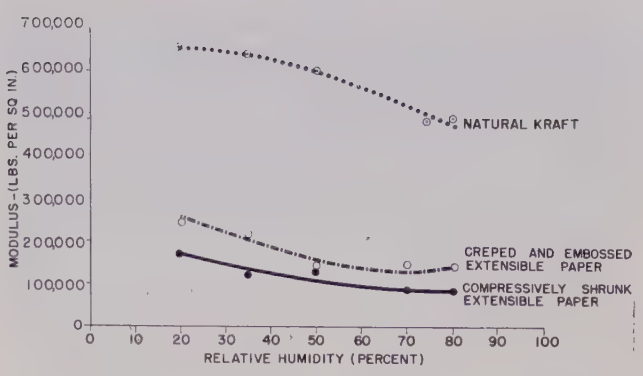
NATURAL KRAFT
CREPED AND EMBOSSED EXTENSIBLE PAPER
COMPRESSIVELY SHRUNK EXTENSIBLE PAPER
MODULUS - (LBS. PER SQ IN.)
RELATIVE HUMIDITY (PERCENT)

Fig. 13. Effect of relative humidity on apparent modulus of elasticity of bag papers, machine direction

and the results obtained are very dependent on single fiber strength and on the ease of distortion of the material. The less readily a cloth can be distorted, the greater the support a weak place will receive from its neighbor.

A possible working mechanism of failure of extensible sacks is suggested by the effect of humidity changes on recovery, rigidity, and tearing strength characteristics of the materials in corroboration with field performance of multiwall sacks and the stress-strain characteristics of these materials at high rates of elongation. It would appear that failure as the result of dropping a bag is a two-part phenomenon. The first part is the localized destruction of fibrous bonds or elements, which in turn will increase the effective load on the other areas. If the web structure is rigid, the increase in stress will be distributed more uniformly, thereby reducing the forces adjacent to the localized failure area. On the other hand, if the material is easily distorted, the load is borne by neighboring fiber elements instead of being shared by all the fiber elements. If the fiber elements adjacent to a failure zone are fixed, concentration of the stress may exceed the strength of the fibers at that point resulting in total failure. Conversely, if the fiber elements are free to orient to the axis of stress concentration, or effectively dampen it, then the load is spread over a greater area, thereby reducing the stress and opportunity to fail. Future work, especially work of a fundamental nature on structure and of tearing resistance, IRE, apparent modulus, and wounded tensile to sack failure, will be necessary to confirm, deny, or modify this proposal.

SUMMARY

To summarize, humidity can have a very great effect on the tearing strength and some of the stress-strain characteristics of sack materials. The importance of the recovery properties of the paper, as indicated by the positive correlation of IRE with elevator bag drops of sewn bags at 50% R.H., and the effect of humidity on these recovery properties warrants the inclusion of their measurement in a testing pro-

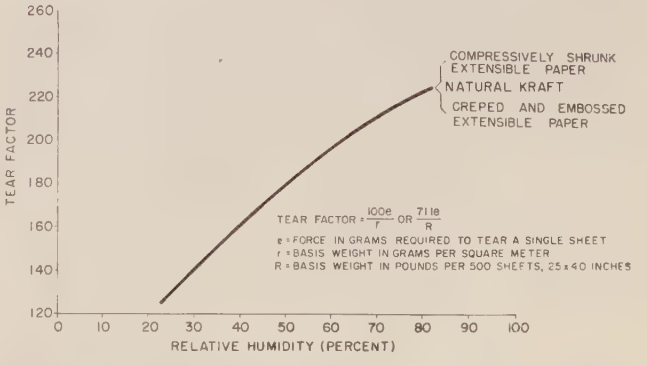
COMPRESSIVELY SHRUNK EXTENSIBLE PAPER
NATURAL KRAFT
CREPED AND EMBOSSED EXTENSIBLE PAPER
TEAR FACTOR = 100e/r OR 711e/R
e = FORCE IN GRAMS REQUIRED TO TEAR A SINGLE SHEET
r = BASIS WEIGHT IN GRAMS PER SQUARE METER
R = BASIS WEIGHT IN POUNDS PER 500 SHEETS, 25 x 40 INCHES
TEAR FACTOR
RELATIVE HUMIDITY (PERCENT)

Fig. 14. Effect of relative humidity on tearing strength for bag papers, machine direction

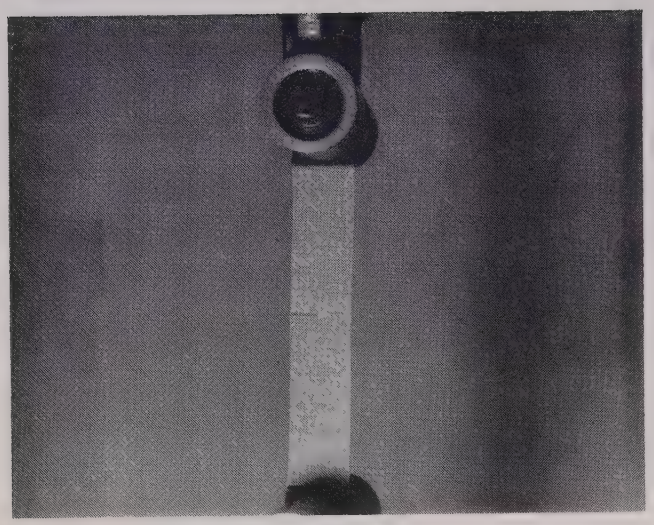

Fig. 15. Wounded tensile specimen

gram. The working mechanism of failure proposed illustrates another aspect of testing which can lead to improved testing methods or products. While the mechanism may not be 100% correct or cover 100% of the cases, it serves the important function of partitioning a very complex problem into simpler elements. Future work then will either substantiate or eliminate the propositions and eventually a true understanding will evolve.

Since the curves presented in this paper represent averages of several tests, they may be useful as references.

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4. Taylor, H. M., *J. Text. Inst.* 50, No. 1: T161–T187 (Jan., 1959).

Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

Moderator Birdsall: The meeting is now open to a discussion of this paper, and Dr. Clark, will you lead off the discussion?

Dr. Clark: Mr. Chairman, Mr. Carlson has given us a very interesting paper. It is a pity that I did not have a copy before the meeting for study, because evidently it has a lot of interesting information and is difficult to discuss intelligently from a short presentation. There are one or two points, however, I think we might look at. A. R. Ewing (Bemis Bros. Bag Co.) has posed several questions: "No mention is made of the temperature employed. Can it be assumed that it was held constant and only the relative humidity changed? If so, was it the standard temperature of 73°F.?"

Mr. Carlson: That is correct, 73°F.

Dr. Clark (reading Mr. Ewing's question): "In Fig. 7, the percentage IRE is plotted against relative humidity. It serves the intended purpose but I am wondering if the absolute IRE rather than the percentage might not more dramatically reveal differences between the several types of materials. Would it not enable a better prediction of the relative elevator drop performance between bags made from extensible and nonextensible paper?"

Mr. Carlson: In all of these, the IRE's are actual which are per cent of recovery of original specimen length. The only per cent of extension we used was one illustration, Fig. 5, showing that as one increases the extension, recovery increases up to a point.

The test that we have outlined involves taking the specimen to 85% of its total extension, holding 5 min., returning at a rate of half an inch per minute. This is the test we have outlined.

We have studied conditions in time, rates of extension, per cent extensions, and feel that this is the useful range in application to materials.

Dr. Clark: I have a third question from Mr. Ewing as follows:

"Figure 11 indicates that creped and embossed extensible paper behaves somewhat different from compressively shrunk extensible paper as the relative humidity increases. I assume that the first item is DuoSTRess and the second Clupak. Can you explain why they behave differently?"

Mr. Carlson: When we get into the manufacturing of these materials, I think we are in a difficult area because we not only have to consider small, narrow, slow machines, but large, fast, wide machines. We found that many of these properties are dependent upon machine conditions. Therefore, to try to specifically relate one to the other, particularly not knowing too much about what some of these other processes are, could lead us to some erroneous conclusions.

However, the main thesis, I believe, is that the initiation of failure in paper is a bond failure. The bonds commence to break when a strain is applied.

The rate of bond breakage may change after the material is held at a given length. There is not one catastrophic failure but there is a series of many small failures and more fundamental work has to be done.

Dr. Clark: When you talk about the bond breaking, you are referring also to the fiber breaking as well, are you not?

Mr. Carlson: It could be. We have done much of the work on model fibers, many times stronger than the bonds. The fibers could very well break.

Dr. Clark: I raised that point because Dr. van den Akker showed a surprising proportion of fibers broke in paper rather than bonds.

Mr. Carlson: However, here we get into a discussion of the initiation of failure and propagation of failure. There is no question of fibers breaking in propagation but in initiation that has to be established.

Dr. Clark: Mr. Ewing also makes this comment:

"Figure 11 indicates that creped and embossed extensible paper continues to increase in TEA up to about 65% R.H., whereas in compressibly shrunk extensible paper it starts to drop off at about 45% R.H. It also indicates that at all levels of relative humidity the first item exhibits higher TEA. Have you any theories on this?"

Mr. Carlson: Well, I think that we could go backward one step here and perhaps it would have been better to leave the designation of materials out of these charts. In one case the materials were made on small machines and in other cases they were made on several large machines by different processes, not by one process.

When we talk about the integrated product of two things, in this case tensile and stretch, both rates are involved. I don't place much significance on the fact that one is at 65 and one is at 45. When we understand bonding better, the effect of humidity on bonding, does the bonding actually become weaker and what have you, then this, I think, will give us a more plausible explanation. We are just illustrating at this point and I wish that it would be restricted to that.

We are illustrating that humidity has a direct effect upon this property, depending upon the mode of manufacture. Any of these levels can be changed up or down by merely increasing the stretch.

It happened that the material that was on top had probably greater total stretch and a higher apparent modulus of elasticity than the average of materials below. Therefore, I do not place too much significance upon the fact that one is different from the other.

Dr. Clark: The other remaining question, I suppose, also can be answered simply:

"Have you made any similar studies of the behavior of

flat and extensible kraft papers that have been treated for wet-strength properties?

Mr. Carlson: We have and, to the best of my knowledge, there may have been some reduction in the rate of descent of some of these materials but not very much. It did not stay level, or did not go up. This poses many questions about mechanism of wet strength.

Dr. Clark: A question was raised by R. E. Linde (Crown Zellerbach Corp.) as to why you didn't examine the properties in cross direction. I take it, in a way, that the breaking or bursting of bags is somewhat similar to a mullen tester, where the failure occurs in the direction in which there is the least stretch and in case of normal paper that is in the machine direction. Would that be the explanation?

Mr. Carlson: In the case of extensible paper, the axis of major stretch may be in the machine direction. We have examined all these properties in cross direction and we find cross direction is dependent upon position in the machine. Generally cross direction properties are good in recovery.

I believe that a paper on the study of these cross directions would be equally as important and just as lengthy as this one.

Dr. Clark: I also have two questions from J. H. Mappus of the West Virginia Pulp and Paper Co.:

"The IRE appears to be a function of the stress-strain curve and independent of basis weight. Is such the case?

Mr. Carlson: I would say, generally, yes. We have found no strong basis of weight function here. There is no correction that has to be made for it.

Dr. Clark: The next question is as follows:

"Would you give more details on the procedure used in the correlation of IRE and drop tests?"

Mr. Carlson: We deemphasized this in this paper because we did not want to feel that we were foisting a new test on the industry. This is not true. I don't believe this test will become a routine test. It takes on the order of an 8-hr. day to run six samples. However, in this correlation study, we included sewn bags of flat kraft, dry crepe kraft, wet creped and embossed, and compressively shrunk krafts. We also included webs made out of viscose, nylon fibers, and the like. A general correlation was found between the elevator flat drops of sewn bags and the product of IRE and total bag weight at 50% R.H. However, this does not mean that a correlation at 50% R.H. can be extended to all ranges. This is not valid. However, we did get a very strong correlation in the machine direction properties. We did not get any correlation of delayed recoverable properties, plastic properties, or cross direction properties.

Carl F. Ackerman (Union Mills Paper Manufacturing Co.): You mentioned that the cross machine directional properties have some influence, depending upon the position?

Mr. Carlson: Yes.

Mr. Ackerman: Do you also find a position a similar case for machine direction properties with web position?

Mr. Carlson: Yes, but not as strong. We did not do a thorough study on this. We had some ideas but we feel that the tension during drying does affect the properties. In other words, by increasing the tension in cross direction, which occurs in the center of the web, you also increase the tension in the machine direction in the center of the web.

Robert C. Williams: Could we take a look at your slide of the TEA versus the relative humidity?

Mr. Carlson: That is Fig. 11.

Mr. Williams: If you will notice the curve for natural kraft, you will find that it shows very little change in TEA with relative humidity. The extensible papers, however, after about 45% R.H., drop fairly rapidly in TEA. Now, this drop doesn't seem to be borne out by your curve on tensile strength versus relative humidity and stretch versus relative humidity. Would you explain this please?

Mr. Carlson: Well, this is an integrated product and so when we look at the other curve we are looking at two peaks. Now in this curve, we are looking at the integrated area under the curve. As you know, you increase relative humidity and as a result the modulus decreased. Therefore, the build up of the TEA will be at a slower rate. Now the Europeans, I believe, have approached this problem but introducing another factor—the product at tensile times stretch, which would be a rectangle, and then they calculate the per cent of area which might be 0.6% in one case and 0.7% in another case, and then they introduce this factor into the standard testing.

Now, as you increase humidity, the percentage will go down as your modulus goes down, and, therefore, the TEA will not necessarily be in direct relation to the two products.

It is interesting to see how with certain grades of paper the per cent area of the rectangle in stretch is fairly constant with a given humidity.

Mr. Williams: The shape of the curves for extensible paper are fairly similar, are they not?

Mr. Carlson: Yes. I think that the major difference in the two products is the moisture at which it was creped or shrunk. One was done very wet and one was done in the area of 35% or thereabouts.

Dr. Clark: This paper has opened up a very interesting approach to some fundamental problems of paper and no doubt we are going to see a great deal more of the matter. It has been very interesting.

Moderator Birdsall: The next paper on this morning's program is entitled, "Hygroexpansivity of Tabulating Cards," by T. D. Callinan, J. S. Crimi, P. M. Schwartz, and L. H. Wirtz of the International Business Machines Corp., at Yorktown Heights, N. Y. This paper will be presented by Mr. Callinan, who is manager of paper and ink research at IBM. Mr. Callinan received his B.S. in Chemistry from St. Peter's College in New Jersey. He is presently engaged in directing studies on the fundamental properties of paper. Mr. Callinan.

The Hygroexpansivity of Tabulating Cards

T. D. CALLINAN, J. S. CRIMI, P. M. SCHWARTZ, and L. H. WIRTZ

The hygroexpansivity of five tabulating card stocks have been determined over the relative humidity range 0 to 98%. A Thwing-Albert NBS Expansimeter was employed in the tests. Unbleached sulfate, semibleached sulfate and semibleached sulfite stocks were studied. Their chemistry, fiber distribution, and moisture adsorption isotherms were determined. The effect of humidity cycling on the hygroexpansivity coefficients were established. The anamolous decrease in dimensions which occurs at elevated humidities has been studied. The hygroexpansivity coefficient has been found to depend in part on the magnitude and relaxation times of strains which develop in the card stock during manufacture.

Tabulating cards expand and contract with changes in relative humidity. While this does not amount to much—less than 0.0184 in. when the humidity changes from 20 to 75%—it sometimes leads to misregistration.

It was the purpose of the studies here to analyze the phenomenon of hygroexpansivity in tabulating cards and to establish the factors which contribute to it. The problem was somewhat complicated by the fact that tabulating card stock is not a unique material; the properties of the five different card stocks used in these studies are listed in Table I. While many of these properties are of prime importance to the proper functioning of the stock—coefficient of friction, stiffness, and warp—only the nature of their expansion and contraction were studied and are reported here.

T. D. Callinan, J. S. Crimi, P. M. Schwartz, and L. H. Wirtz, International Business Machines Corp., Research Center, Yorktown Heights, N. Y.

Table I. Physical Properties of Select Tabulating Cards

Color →	A Brown	B Natural	C Natural	D Natural	E White
Pulp					
a. Semibleached sulfite	0	90%	0	0	0
b. Semibleached sulfate	0	5%	100%	25%	0
c. Hardwood	0	5%	0	0	0
d. Unbleached sulfate	100%	0	0	0	0
e. Bleached sulfate	0	0	0	0	20%
f. Bleached and deinked waste paper	0	0	0	75%	0
g. Bleached sulfite semichemical hardwood	0	0	0	0	80%
Basis weight, lb. (24 × 36–500)	100.3	98.6	97.1	100.8	101.0
Thickness, mils	7.1	7.3	7.2	7.8	7.4
Bursting strength	76	59	58	61	75
Tensile strength, MD	76.4	68.0	59.6	65.8	69.4
Tensile strength, CD	50.6	38.6	36.0	36.2	46.0
Tearing resistance, MD	233	136	194	158	128
Tearing resistance, CD	247	131	169	166	122
Stiffness (Taber-V-5), MD	18.8	23.2	17.2	21.8	19.2
Stiffness (Taber-V-5), CD	10.4	12.8	9.5	10.5	10.2

The hygroexpansions in the machine (MD) and cross-machine (CD) directions of the cards were determined in an NBS Expansimeter, manufactured by the Thwing-Albert Instrument Co. This instrument is capable of testing eight card samples simultaneously. Each card is suspended in a vertical position between clamps, the lower one of which is fixed in place while the top one is pulled upward by a chain which passes over a pulley and is kept taut with a hanging 150-g. weight. The tension amounts to 23 p.s.i. A small mirror is mounted on the shaft of each pulley. A beam of light impinging on a mirror is reflected onto a translucent screen. Any movement of the pulley is thus easily observed on the screen. This test method has advantages over the more conventional ones in that the samples remain in an uncurled condition and require no manual handling during the humidity cycling. The instrument is shown in Fig. 1.

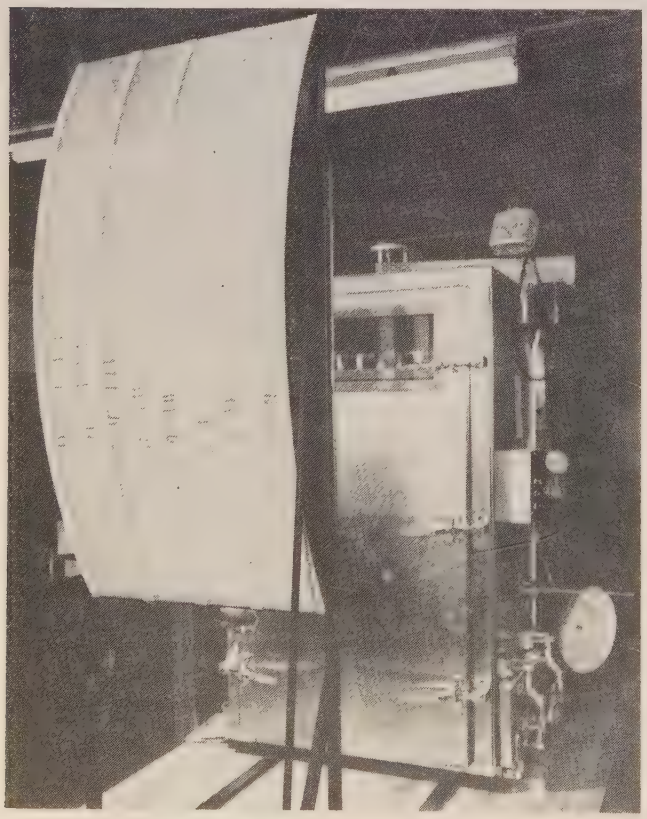


Fig. 1. The NBS Albert Hygroexpansimeter

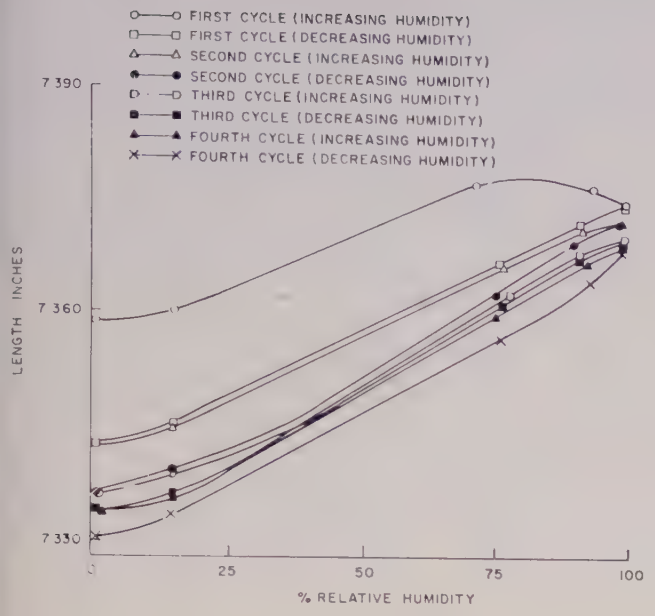
Table II. Expansion in the Machine Direction of Five Select Tabulating Cards

Relative humidity	A	B	C	D	E
	First Cycle (Increasing Humidity)				
0	7.359	7.361	7.360	7.358	7.356
15	7.362	7.363	7.363	7.361	7.360
75	7.378	7.376	7.375	7.378	7.380
92	7.378	7.379	7.372	7.382	7.387
98	7.375	7.380	7.371	7.383	7.390
	First Cycle (Decreasing Humidity)				
0	7.343	7.350	7.340	7.342	7.338
15	7.348	7.355	7.346	7.348	7.346
75	7.367	7.373	7.364	7.372	7.375
90	7.372	7.378	7.369	7.380	7.385
98	7.375	7.380	7.371	7.383	7.390
	Second Cycle (Increasing Humidity)				
0	7.343	7.350	7.340	7.342	7.338
15	7.348	7.354	7.345	7.347	7.344
75	7.367	7.370	7.362	7.370	7.371
90	7.371	7.376	7.366	7.376	7.380
98	7.372	7.378	7.367	7.380	7.387
	Second Cycle (Decreasing Humidity)				
0	7.337	7.350	7.337	7.348	7.338
15	7.342	7.355	7.344	7.346	7.344
74	7.363	7.371	7.361	7.370	7.373
90	7.370	7.375	7.367	7.376	7.381
98	7.372	7.378	7.367	7.380	7.387
	Third Cycle (Increasing Humidity)				
0	7.337	7.350	7.337	7.338	7.334
15	7.342	7.353	7.342	7.344	7.342
76	7.363	7.371	7.358	7.365	7.368
92	7.368	7.375	7.364	7.375	7.380
98	7.370	7.378	7.367	7.379	7.387
	Third Cycle (Decreasing Humidity)				
0	7.335	7.350	7.339	7.338	7.334
15	7.338	7.353	7.342	7.344	7.342
75	7.361	7.370	7.359	7.368	7.371
90	7.368	7.376	7.364	7.374	7.381
98	7.370	7.378	7.366	7.379	7.387
	Fourth Cycle (Increasing Humidity)				
0	7.335	7.350	7.337	7.338	7.334
15	7.338	7.353	7.340	7.344	7.340
74	7.360	7.370	7.358	7.365	7.368
92	7.367	7.374	7.363	7.373	7.378
98	7.370	7.377	7.366	7.378	7.387
	Fourth Cycle (Decreasing Humidity)				
0	7.332	7.348	7.334	7.336	7.333
15	7.336	7.353	7.340	7.343	7.342
74	7.358	7.370	7.358	7.368	7.371
92	7.365	7.375	7.364	7.374	7.380
98	7.370	7.377	7.366	7.378	7.387

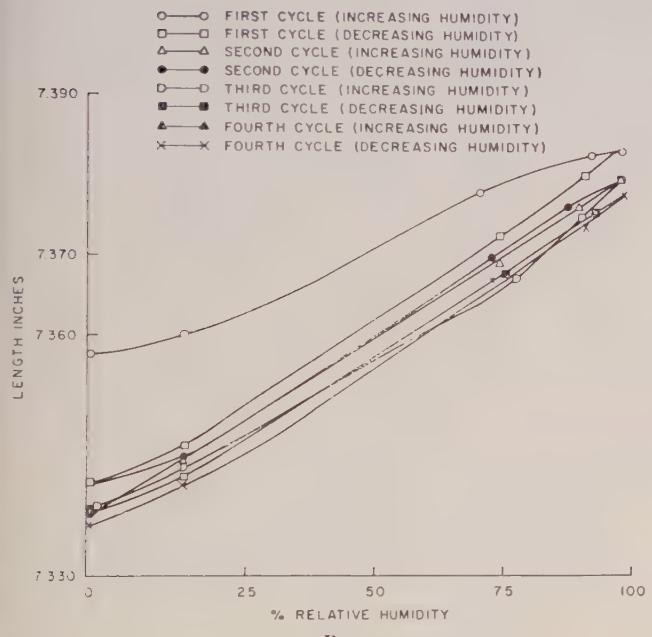
For the hygroexpansion determinations in the machine direction (MD) samples 2 x $7^3/_8$ in. were cut from the cards and were placed in the expansimeter; the atmosphere in the machine was reduced to approximately 0% R.H. initially through the use of Drierite. After the card had reached equilibrium (approximately 16 hr.) and a zero reading established, saturated solutions of salts were introduced in sequence to produce relative humidities of 15, 75, 92, and 98%, respectively. The actual relative humidities were determined using a wet bulb thermometer. The results of four cyclings between 0 and 98% R.H. are listed in Table II and are presented graphically in Fig. 2.

Each card was found to act differently when subjected to an ambient of increasing relative humidity.

Card A expanded moderately as the humidity of its surroundings were raised up to 75% R.H.; at higher humidities it underwent contraction. On being subjected subsequently



A



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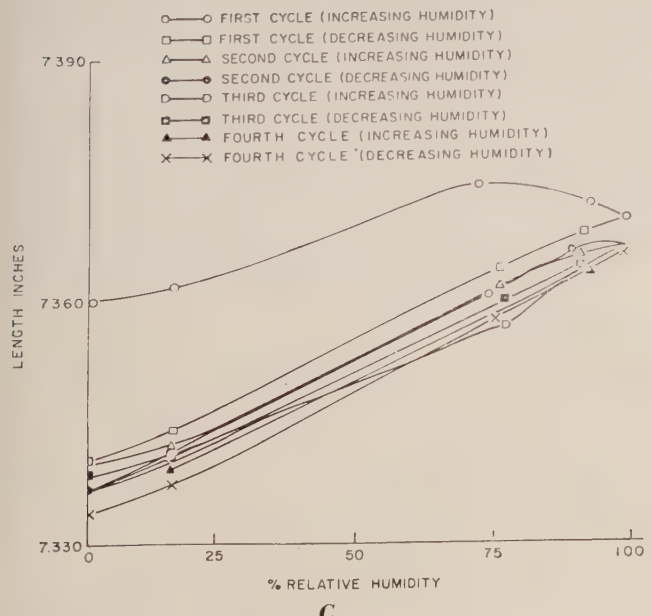

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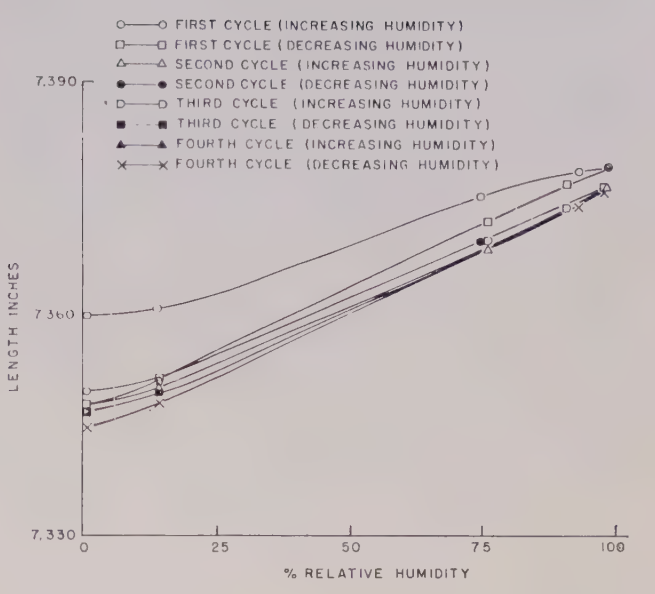

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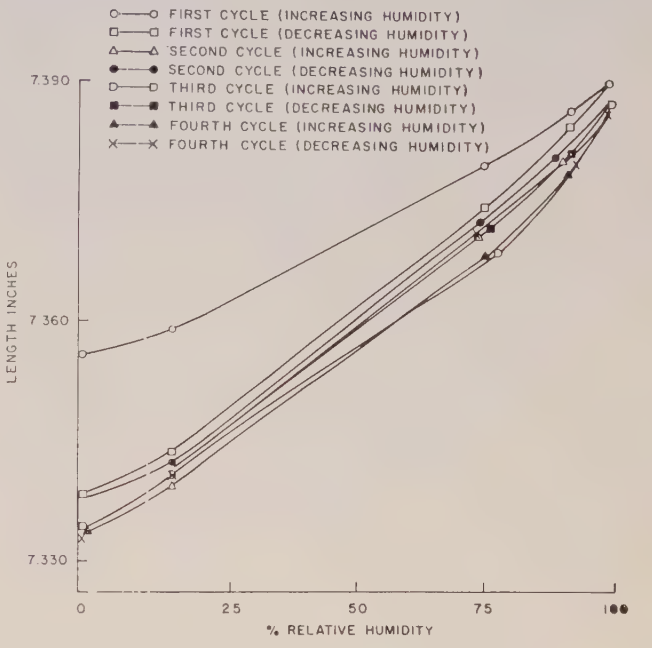


E

Fig. 2. The hygroexpansivity in the machine direction of select tabulating cards

to a decreasing humidity, the card contracted but was shorter by 0.014 in. On the next cycle the card, on expanding, practically retraced the former contraction curve, but again on reaching 98% R.H. it contracted slightly. When it was next dried out, it was 0.008 in. shorter than previously and 0.022 in. shorter than it was initially. The slope of the curve had changed appreciably. Even two more cycles did not completely stabilize the card in that the card was found to be 0.002 in. shorter at the completion of each cycle. Because of this, no hysteresis strictly so-called was observed. The slope of the curve between 20 and 75% was 0.00038 inch per % R.H.

Card B exhibited some of the same characteristics as card A in that it showed a gradual expansion in length as the humidity increased. No maximum in expansion at 80% R.H. was observed however. On contracting, the card was found to be 0.010 in. shorter than it was initially. Subsequent cycling resulted in a decrease of another 0.006 in. Again, the slope of the curves had increased.

Card C resembled card A in that it underwent a significant and permanent contraction in length during the humidity cycling. A maximum appeared in the length versus relative

Table III. The Hygroexpansion of Five Select Tabulating Cards Between 20 and 75% R.H.

Relative humidity	*A*	*B*	*C*	*D*	*E*
1st Cycle	0.016	0.013	0.013	0.017	0.020
2nd Cycle	0.019	0.016	0.017	0.023	0.027
3rd Cycle	0.022	0.018	0.016	0.021	0.026
4th Cycle	0.022	0.017	0.019	0.022	0.028

humidity curve at 75% and the total permanent contraction during the first cycle amounted to 0.020 in. Repeated cycling resulted in a subsequent permanent shrinkage of 0.008 in. The slope of the curve remained constant after the first cycle even though the dimensions of the card had changed significantly.

Card D resembled card B in that its length versus relative humidity curve during the first cycle rose without passing through a maximum as the moisture content rose. It differed from card B, in that the slope of the curve was initially greater. After four cycles, it shrank permanently 0.022 in. and its slope had increased appreciably.

Card E differed from all the other cards in that it expanded continuously as the humidity rose. After the first cycle it had shrunk permanently 0.018 in. when tested dry and after more cyclings it had shrunk another 0.006 in. Again the slope had increased appreciably.

For the purpose of comparison, the expansion curves of all five cards during the first half-cycle of increasing relative humidity is plotted in Fig. 3. The change in length of the cards between 20 and 75% R.H. humidity are listed in Table III. Card B and card C expanded only 0.013 inches. Card A expanded 0.016 in. and Card D 0.017 in. Card E expanded 0.020 in.

The dimensional changes which the cross-machine direction of the tabulating cards undergo on being cycled from 0 to 98% R.H. humidity and back again are listed in Table IV and presented graphically in Fig. 4.

The width of card A increases with increasing humidity continuously, and decreases when the humidity is reduced. It can be seen, however, that the card has expanded permanently 0.010 in. after being cycled only once. The slope of the two curves between 20 and 75% R.H. are the same for both increasing and decreasing moisture conditions. The second cycle of increasing humidity did not repeat the same curve, however, and the slope between 20 and 75%

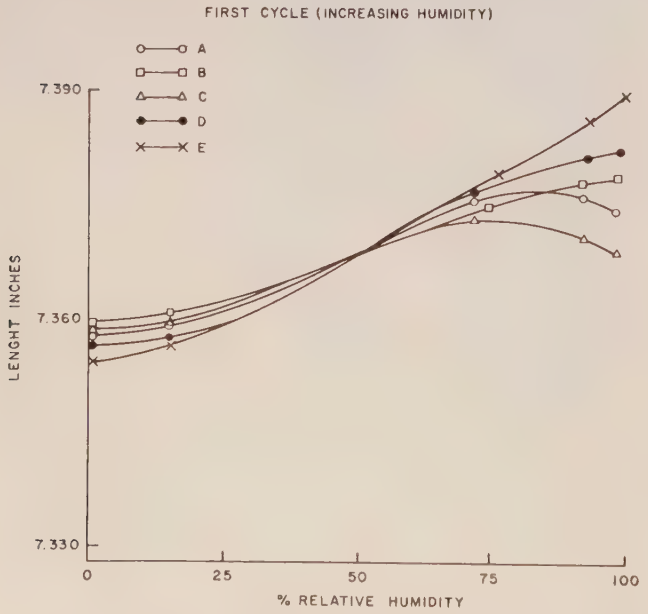


Fig. 3. The hygroexpansivity of five tabulating cards during their first cycle (increasing humidity)

Table IV. Expansion in the Cross Machine Direction of Five Select Tabulating Cards

Relative humidity	*A*	*B*	*C*	*D*	*E*
	First Cycle (Increasing Humidity)				
0	3.237	3.240	3.237	3.238	3.229
15	3.240	3.244	3.242	3.241	3.236
74	3.265	3.259	3.265	3.267	3.271
92	3.283	3.270	3.284	3.277	3.283
98	3.307	3.283	3.307	3.295	3.306
	First Cycle (Decreasing Humidity)				
0	3.247	3.240	3.238	3.234	3.235
15	3.251	3.243	3.246	3.239	3.242
74	3.281	3.266	3.278	3.268	3.277
92	3.296	3.277	3.295	3.284	3.299
98	3.307	3.283	3.307	3.295	3.306
	Second Cycle (Increasing Humidity)				
0	3.247	3.240	3.238	3.234	3.235
15	3.249	3.243	3.243	3.238	3.239
74	3.274	3.259	3.268	3.261	3.276
92	3.289	3.273	3.289	3.276	3.292
98	3.310	3.282	3.307	3.295	3.300
	Second Cycle (Decreasing Humidity)				
0	3.247	3.238	3.239	3.232	3.236
15	3.253	3.244	3.244	3.238	3.240
74	3.282	3.261	3.277	3.267	3.277
90	3.295	3.273	3.294	3.283	3.293
98	3.310	3.282	3.307	3.295	3.300
	Third Cycle (Increasing Humidity)				
0	3.247	3.238	3.239	3.232	3.236
15	3.250	3.243	3.243	3.236	3.240
75	3.277	3.262	3.269	3.261	3.277
90	3.292	3.272	3.286	3.277	3.292
98	3.307	3.282	3.307	3.295	3.300
	Third Cycle (Decreasing Humidity)				
0	3.247	3.238	3.237	3.232	3.236
15	3.253	3.245	3.244	3.236	3.241
74	3.283	3.265	3.274	3.263	3.277
92	3.300	3.273	3.291	3.281	3.294
98	3.307	3.282	3.307	3.295	3.300

decreased. The second cycle resulted in a slight 0.002 in. permanent increase in width.

Card B differed from card A in that it underwent a permanent contraction when moisture free of 0.002 in. due to humidity cycling. Card C, on the other hand, experienced a permanent expansion while card D underwent a permanent contraction due to moisture cycling. Card E expanded 0.005 in. permanently. For the purpose of comparison the data obtained on the samples as they were subjected to the first cycle are presented graphically in Fig. 5. Card B expanded the least while card E expanded most.

There are two changes which arise in the cross-machine direction of the cards due to humidity cycling (Table V). The first is that the cards after humidity cycling have permanently changed in width. This change measured at 50% R.H. and 73°F. amounts to a permanent increase in width of 0.014 in. for card A and 0.003 in. for card C. Card D shrank permanently 0.005 in.

The second effect of humidity cycling is that the coefficient of hygroexpansivity in the cross-machine direction is changed only slightly or not at all.

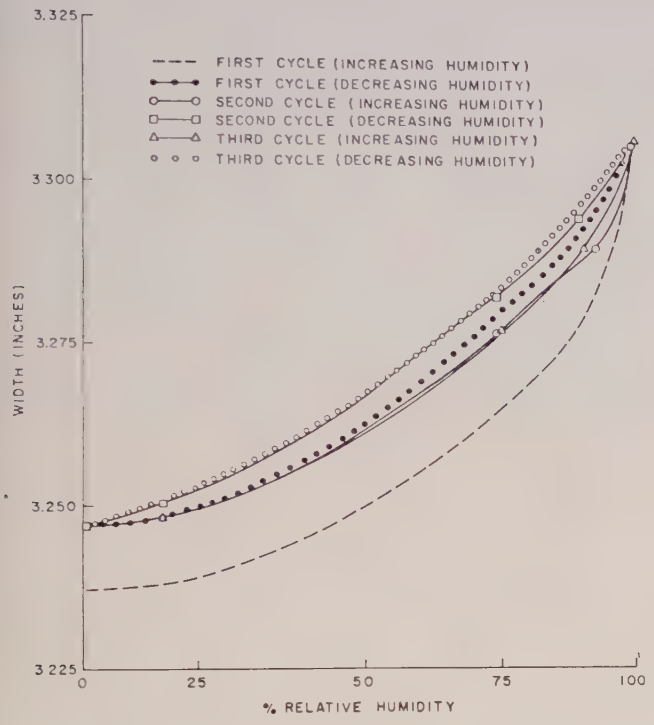
RATE OF PERMANENT DIMENSIONAL CHANGES IN CARDS

Examination of the previous data reveals that all the cards underwent permanent dimensional changes on being subjected to elevated humidities.

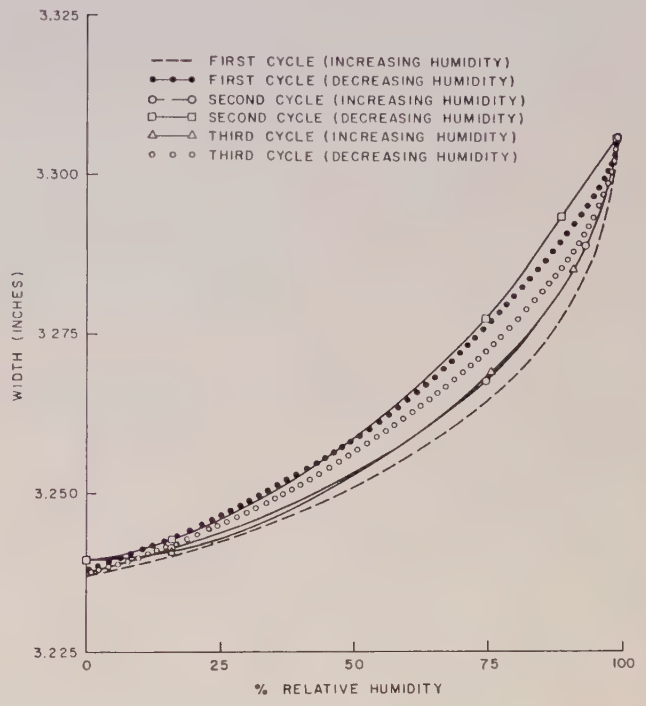
In an effort to establish the kinetics of this phenomenon, the lengths and widths of the five commercial card stocks were determined accurately. Then ten cards of each type were placed in three desiccators containing saturated aqueous

Table V. Effect of Moisture on the Width of Select Tabulating Cards

	Permanent change in width (inches) after three humidity cycles				
	A	*B*	*C*	*D*	*E*
(a) First cycle (increasing humidity)	3.247	3.250	3.250	3.250	3.250
(b) Third cycle (increasing humidity)	3.261	3.250	3.253	3.245	3.253
(c) Change in width, inches	+0.014	0.000	+0.003	−0.005	+0.003
	The change in width (inches) as the humidity is raised from 20% R.H. to 75%				
(a) First cycle (increasing humidity)	0.026	0.024	0.025	0.025	0.037
(b) Third cycle (increasing humidity)	0.027	0.029	0.027	0.026	0.037



A



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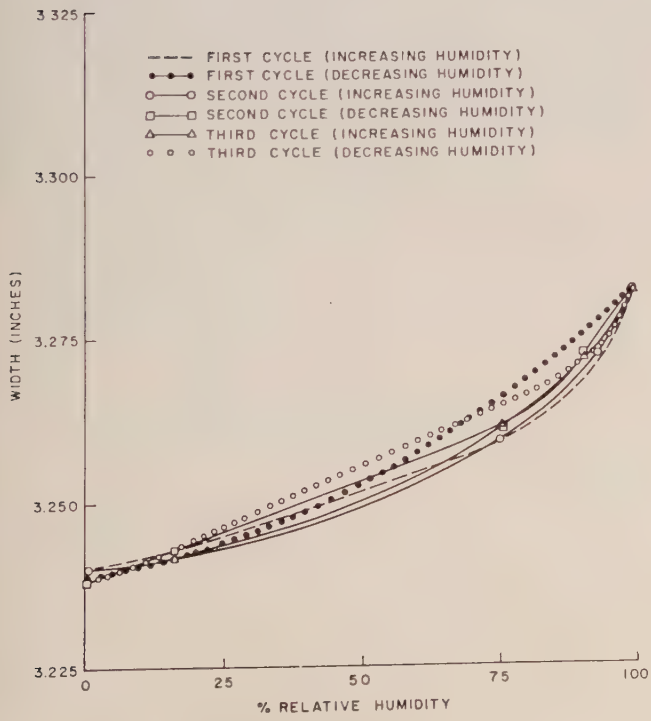

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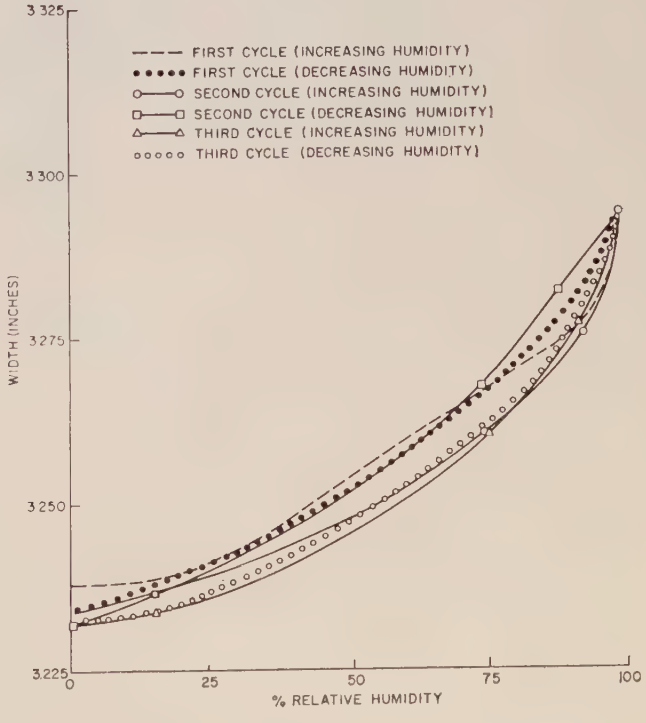
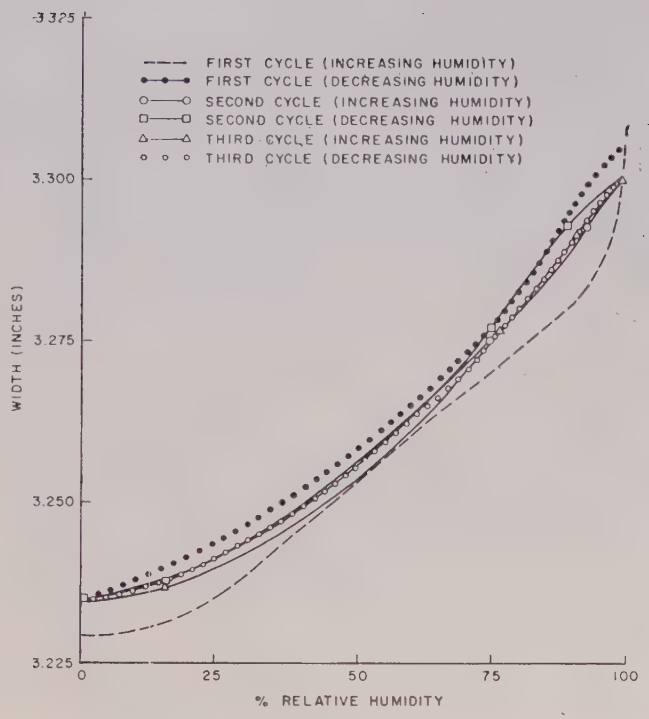


D



E

Fig. 4. The hygroexpansivity of five select tabulating cards tested in the cross machine direction

solutions of sodium chloride (75% R.H.) and sodium dihydrogen phosphate (92% R.H.) and pure water (98% R.H.), respectively. Cards were removed from these highly humid conditions at various times, allowed to reach equilibrium at 50% R.H. and 73°F. and their dimensions were remeasured. The permanent shrinkage in lengths are given in Table VI and are plotted graphically in Fig. 6.

For the sake of comparison the shrinkage at 98% R.H. humidity is presented graphically in Fig. 7. All five cards

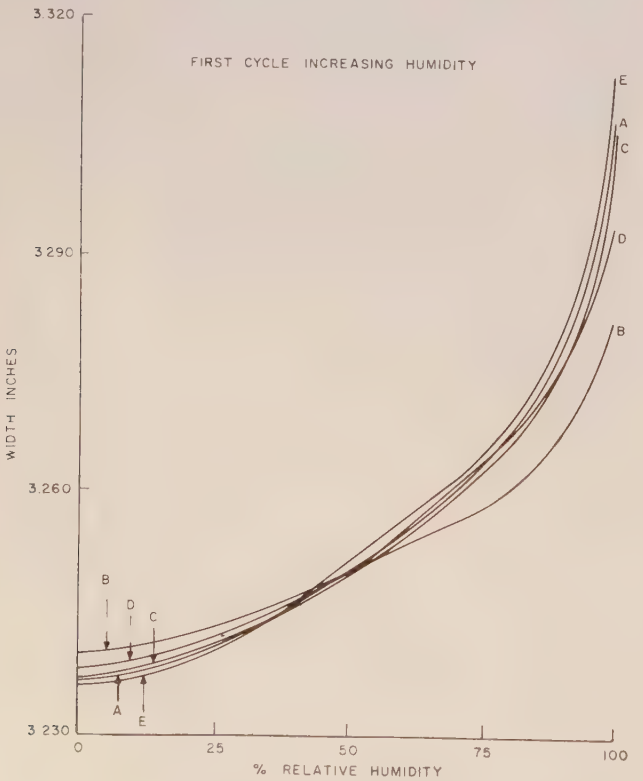


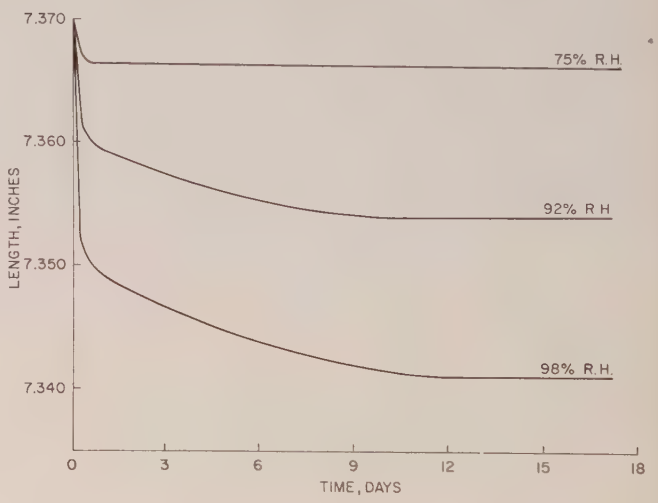
Fig. 5. The hygroexpansivity in the cross direction of five cards on the first cycle of increasing humidity

Table VI. The Permanent Change in Length(MD) of Five Commercial Cards Subjected to High Humidities

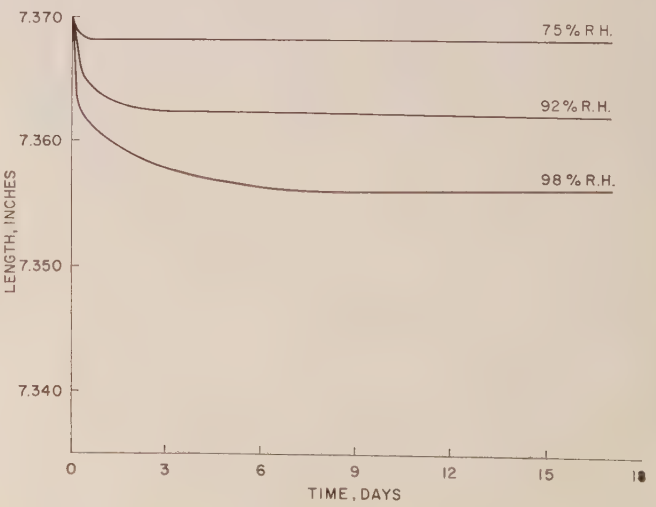
Time in days	*Commercial card A*	*Commercial card B*	*Commercial card C*	*Commercial card D*	*Commercial card E*
		75% Relative Humidity			
0	7.370	7.370	7.370	7.370	7.370
17	7.368	7.368	7.366	7.369	7.366
		92% Relative Humidity			
0	7.370	7.370	7.370	7.370	7.370
0.3	7.361	7.365	7.360	7.365	7.361
1	7.359	7.365	7.357	7.361	7.358
3	7.358	7.365	7.356	7.361	7.358
7	7.358	7.364	7.355	7.360	7.357
10	7.356	7.363	7.354	7.359	7.355
13	7.355	7.362	7.353	7.358	7.354
17	7.354	7.362	7.353	7.358	7.354
		98% Relative Humidity			
0	7.370	7.370	7.370	7.370	7.370
0.3	7.350	7.362	7.350	7.355	7.351
1	7.349	7.360	7.348	7.352	7.349
3	7.347	7.360	7.347	7.352	7.348
7	7.347	7.359	7.345	7.347	7.346
10	7.342	7.356	7.343	7.344	7.344
13	7.342	7.356	7.342	7.343	7.341
17	7.342	7.356	7.342	7.343	7.341

shrank rapidly during the first exposure and then approached their ultimate lengths asymptotically.

During the first day at 98% R.H. all the cards underwent a dramatic permanent shrinkage in the machine direction (MD). This amounted to a permanent shrinkage in length



A



B

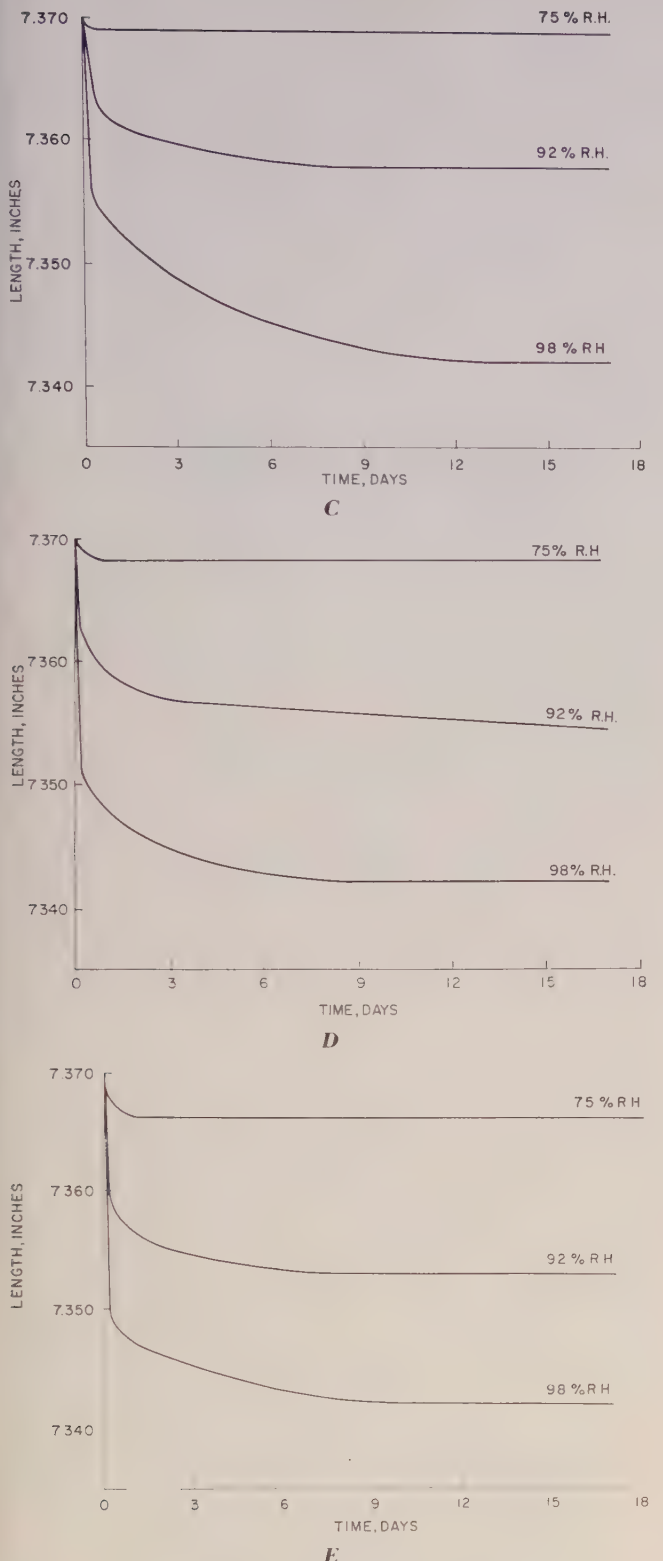


Fig. 6. The change in length of five commercial cards when subjected to high humidities

(MD) of between 5 and 11 mils. After the first day the cards continued to shrink permanently in length (MD) but at a considerably reduced rate.

Examination of the data reveals that each card shrank at a rate which depends upon the relative humidity of its ambient. At 98% R.H., commercial card B shrank least rapidly while commercial card A shrank most rapidly. The rate at which the cards shrank are not linearly dependent on vapor pressure of the ambient. Commercial card A for example shrank at the same rate as commercial card B when both were subjected to 75% R.H. A rise in humidity, however, to 92% resulted in a sevenfold increase in the rate of commercial card A while a similar change in humidity resulted in only a threefold change in the rate factor of commercial card B.

It is conventional to conceive the hygroexpansivity plot

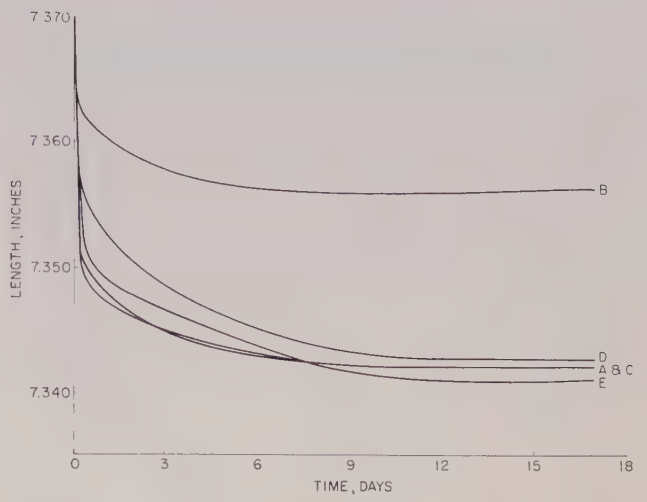


Fig. 7. Comparison of the change in length of five commercial cards when subjected to 98% R.H.

of the last humidity cycle as being closer to the "true" values than any of the data obtained on earlier cycles. The thought underlying this is that the card is relaxing to some equilibrium state. This theory suggests that if the commercial cards were "relaxed" at 98% R.H. humidity for a long period of time and then tested for hygroexpansivity,

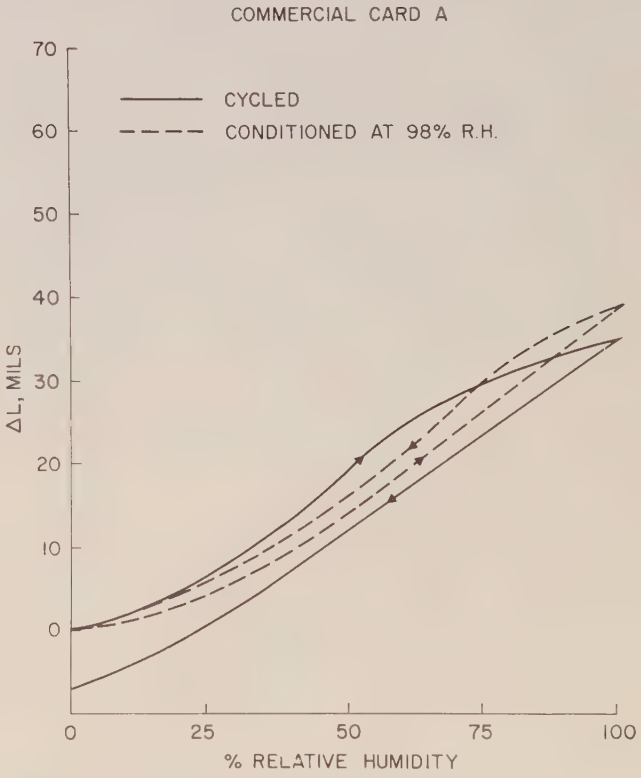


Fig. 8. The hygroexpansivity of commercial card A subjected to two different humidity histories

the resulting curves should correspond to the ultimate ones obtained by cycling. Figures 8 and 9 show that this is not true. Rather than believe that the cards on cycling reach some equilibrium or "true" value, it seems more

plausible to say that the historical process produced different cards out of what were originally the same. Any analysis of hygroexpansivity must consider and explain this phenomenon.

ANALYSIS OF THE RESULTS

It would appear that the shrinkage effect might be interpreted in terms of a classical relaxation mechanism. Such

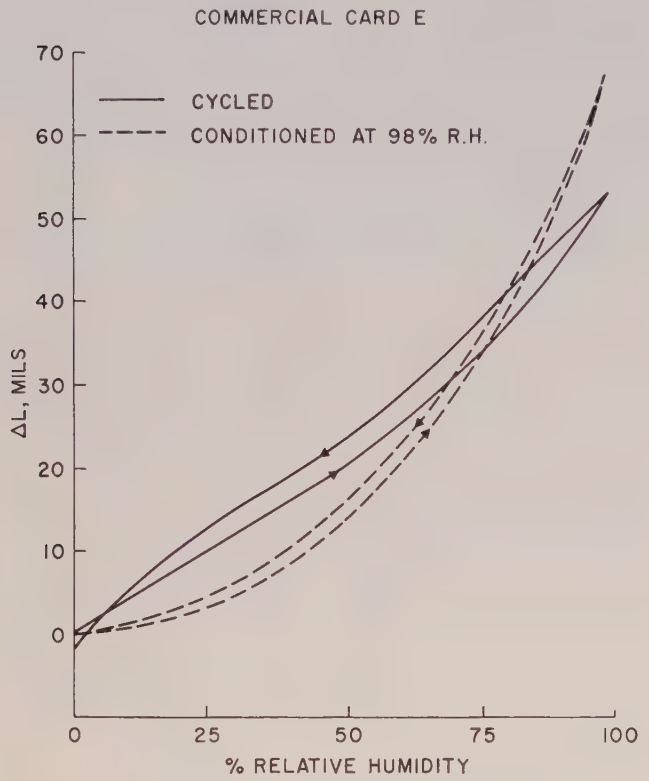


Fig. 9. The hygroexpansivity of commercial card E subject to two different humidity histories

a mechanism envisions the constituent fibers as possessing at least two discrete geometries—one coiled and the other uncoiled. Obviously in nature every intermediate is possible; in the case of wood pulp fibers these lie between that of a dried twisted ribbon structure through a variety of geometries up to that of a wet cylindrical tubing.

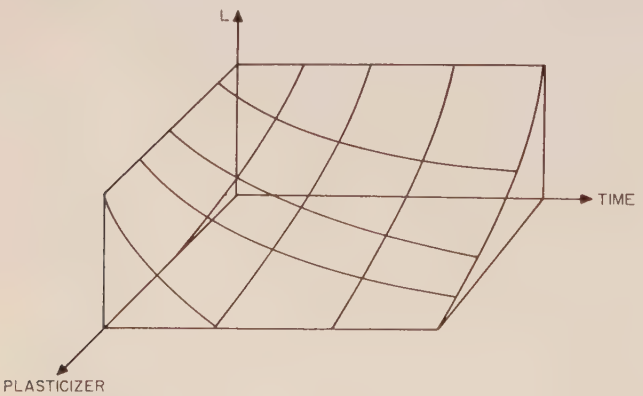


Fig. 10. The dependence of the length of a strained fiberous material on time and plasticizer content

Using such a mechanism then, the rate at which the fiber relaxes from a strained or uncoiled posture to an unstrained or coiled one is dependent upon the concentration of plasticizer. This is shown as the classic three-dimensional plot

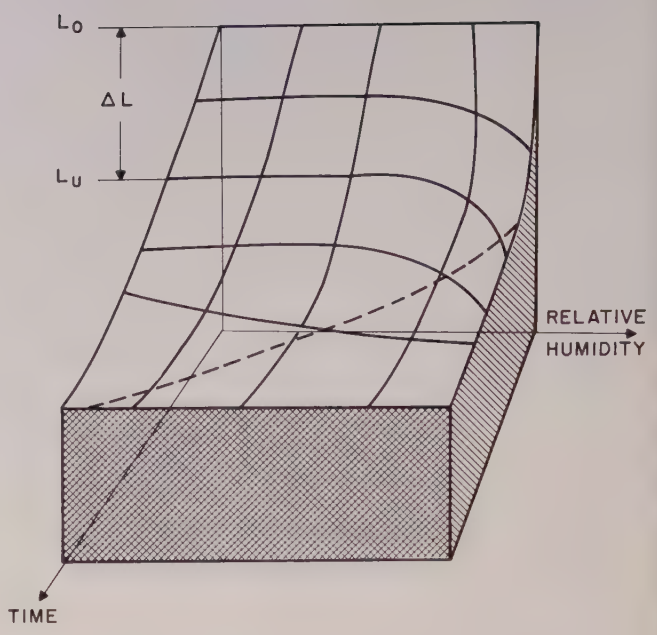


Fig. 11. Idealized plot of the effect of humidity on the rate at which strained cards relax

in Fig. 10. In the case of wood pulp, the moisture is the plasticizer. The effect of relative humidity on the shrinkage of cards is shown graphically as an idealized plot in Fig. 11. Cross sections of this three-dimensional figure correspond to the curves obtained experimentally and shown in Fig. 7. This assumes that if one starts with the same length of paper containing the same amount of strain, in time all the cards will shrink permanently to the same length; the only difference will be the rate at which this happens.

Incidentally, Fig. 11 suggests that the rate of removal of

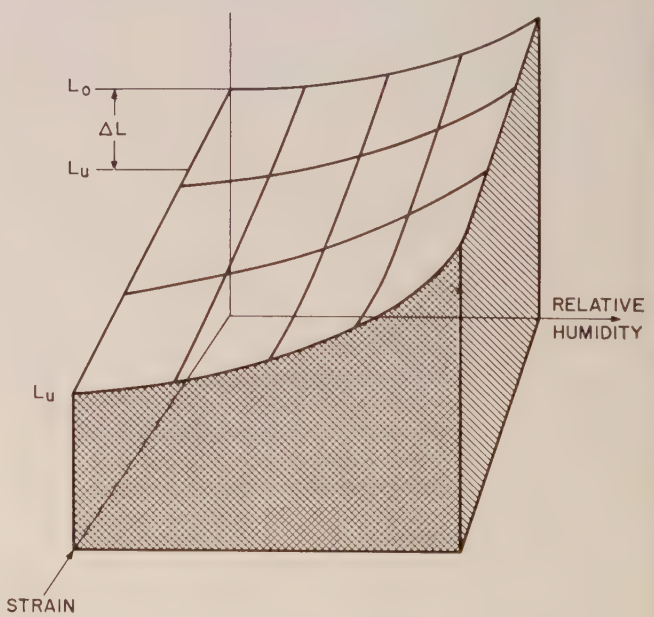


Fig. 12. Idealized plot of the effect of strain on the hygroexpansivity of cards

moisture from a paper affects appreciably the state of the dried sheet. If, for example, the paper were in chemical equilibrium with its surroundings at a very high humidity it would be shrinking and approaching mechanical equilibrium at a high rate. If the moisture content were reduced to zero very rapidly before this state of mechanical equilibrium had

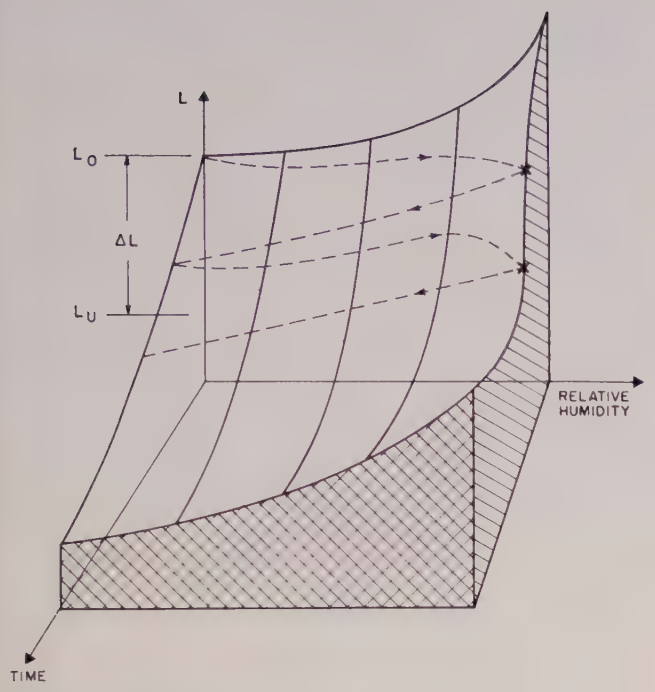


Fig. 13. Idealized plot of the change in length L of a tabulating card with change in relative humidity over a period of time

been reached, the card would retain more strain than if it had been dried more slowly. This probably explains why the cycled and relaxed cards (Figs. 8 and 9) differed.

It seems reasonable to believe that the presence of strains or of unrelaxed fibers in the commercial cards affect appreciably the hygroexpansivity of the cards. Certainly in the case of elastomeric bodies, materials which are strained (that is containing unrelaxed molecules) swell less than unstrained materials of similar chemistry. The effect of strains on the hygroexpansivity may be visualized in terms of the idealized plot shown in Fig. 12. Here it can be seen that a strained card would not expand during the first cycle of humidity as much as would an unstrained card.

By combining the two idealized plots shown in Figs. 11 and 12 into a single three-dimensional model what happens to a strained card when it is subjected to cyclings of increasing and decreasing relative humidities can be seen in Fig. 13. As the humidity rises the card expands according to the law plotted 'n Fig. 11. At the same time, however, it is operating under the law plotted in Fig. 10 which permits the fibers to relax from their strained state. The concomitant action of these two effects results in a curve which is a cross section of Fig. 13. This is the source of the curves shown in Fig. 2.

Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

The authors wish to thank H. O. George and his associates at IBM, Endicott, N. Y., for supplying the informatien on the composition of the cards and the determination of some of their physical properties.

MODERATOR BIRDSALL: We are running between 15 and 20 minutes behind our schedule and so instead of opening the floor at this time for a full discussion of this paper, we would like to limit it to questions of clarification and leave the full discussion until the last paper has been delivered.

Are there any questions of clarification in connection with this paper?

The last formal paper of this morning's session is entitled, "The Effect of Relative Humidity on Paper Properties." It will be presented by W. A. Wink of The Institute of Paper Chemistry, Appleton, Wis. Mr. Wink is chief of the Paper Evaluation Section at the Institute. Mr. Wink.

The Effect of Relative Humidity and Temperature on Paper Properties

W. A. WINK

Examination of the factors that can contribute to the variability in the test result, when the testing is done in an atmosphere controlled in accord with the present TAPPI Standard T 402, indicates that: (1) the temperature and humidity effects are the only two important factors governed by the tolerances of the testing atmosphere; (2) excluding folding endurance, the humidity and temperature effects introduce a variability of the order of a few per cent with the temperature effect appearing to run a little higher than the humidity effect; (3) humidity fluctuations and/or cycling within the testing atmosphere results in a reduced slope in the moisture content-relative humidity relationship so that the actual variability in moisture content is only a few tenths of a per cent (probably well within 0.3% for most papers) for the present humidity tolerances and approaches the accuracy of the moisture content determination; (4) moisture hysteresis effects are several times greater than either the humidity or temperature effects and can account for appreciable variability—the effect is independent of the humidity and temperature tolerances and can be essentially eliminated by always approaching the testing atmosphere from either a drier or a more humid atmosphere; (5) humidity excursions to high relative humidities, exceeding about 65%, introduce swelling and shrinking, and stress relaxation effects, ranging up to 30 to 40% of the property value, that are irreversible, independent of the humidity and temperature tolerances and cannot be recovered by manipulation of the moisture content and/or the relative humidity; and (6) the large magnitude of the humidity excursion and/or stress relaxation effect emphasizes the importance of maintaining control of the moisture content history for achieving intra- and interlaboratory agreement, proper evaluation of the stress relaxed or unrelaxed material, whichever may be of interest, and the avoidance of possible misunderstandings or misinterpretations with regard to specifications and mill-customer relationships. Upon considering the scientific as well as the economic justifications for tightening the present humidity and temperature tolerances, it must be clearly remembered that there are a number of factors (hysteresis, humidity excursions, and stress relaxation) which are not dependent upon the tolerances at all but which can contribute to large variability in the test result. Full recognition of these factors and the implementation of suitable sample-handling techniques to ensure that the sample reaches the testing laboratory in the desired state (stress relaxed or unrelaxed) appears to be the first important step toward reducing the magnitude of potential variables. Beyond this, it would appear that a tightening of the temperature tolerances could be justified. This is a comparatively simple and inexpensive step that could introduce a twofold effect; it could result in a small reduction in the variability of the test result, and it could create the all important condition of temperature stability that is required for maintaining the humidity within close tolerances. On the basis of experiences in this laboratory, tightening the tolerances on humidity can be difficult to achieve in practice and it could indeed represent a costly venture. It is appreciated that properties such as folding endurance are extremely dependent upon humidity control. However, their dependence on humidity is so strong that nearly perfect control would be required to reduce the variability in this property to a few per cent. With

W. A. WINK, Chief, Paper Evaluation Section, The Institute of Paper Chemistry, Appleton, Wis.

respect to most other properties, a tightening of the tolerances to a half of the present value, a difficult achievement even with modern equipment, would yield an improvement of no more than about 1 to 2% or so, in the variability of the test result.

It is, of course, well known that relative humidity has a strong effect on many physical properties of paper, that the physical properties at a given relative humidity depend on whether the paper is conditioned from an atmosphere that is drier or more humid than the controlled atmosphere of the laboratory in which the test is made, and that for control and research purposes paper and paperboard are conditioned and tested in a controlled atmosphere, usually maintained in accord with TAPPI Standard T 402 (50 ± 2% R.H. and 73 ± 3.5°F.). It is, perhaps, not so well known that (1) temperature also has a pronounced effect on the physical properties of paper, (2) stress relaxation of the dried-in stresses in a machine-made paper, resulting from exposure of the paper to a high relative humidity (above about 65% R.H.), can markedly affect the result obtained when the test is made under the conditions of TAPPI Standard T 402, and (3) because of the stress relaxation effect, which is irreversible, the test result obtained under the conditions of TAPPI Standard T 402 can be quite meaningless unless one is fully acquainted with the moisture content history of the sample. It has been the experience in this laboratory that the stress relaxation effect can overshadow, by far, the effects of relative humidity, hysteresis, and temperature. The stress relaxation effect referred to here is unrelated and unaffected by the small excursions in relative humidity and temperature experienced in the testing atmosphere; the effect would be present even if the atmosphere were controlled at exactly 50% R.H. and 73°F.

It will be recognized that the foregoing factors have an important bearing on considerations regarding the humidity and temperature control tolerances of the conditioning and testing atmosphere and the precision of the test result. Advance notices of this symposium indicated that there are some who believe that the present tolerances of TAPPI Standard T 402 are too broad and should be tightened. This belief is shared by the writer with respect to the tolerances on temperature. However, with respect to the relative humidity it would appear that tighter tolerances may not be justified on either a scientific or economic basis.

In order to obtain the necessary background information for judging the adequacy of the present tolerances, published and unpublished data were examined; these were used to determine the order of magnitude of the effect of pertinent variables on the test result obtained over the range of the present tolerances, i.e., 48 to 52% R.H. and 69.5 to 76.5°F. The results of this examination, together with a discussion of the pertinent variables, are given in the following sections of this paper.

MOISTURE CONTENT-RELATIVE HUMIDITY RELATIONSHIP

Extensive studies have been made in the past to determine the sorption characteristics on a large variety of materials. For those who are interested in a more detailed discussion than will be given in this paper, Ott (*1*) has summarized the pertinent work and his book provides a ready source of references. Brecht (*2*), Van den Akker, Wink, and Bobb (*3*), Wink, Bobb, and Van den Akker (*4*), and Wiegerink (*5*) have also discussed various aspects of this subject and their papers provide additional references.

Much of the early work, it will be found, originated in the textile field by Urquhart and Williams (*6–8*), Urquhart (*9*), and Urquhart and Eckersall (*10*) and involved measurements made on cotton. However, the results are generally applicable to cellulose derived from wood and they serve to further

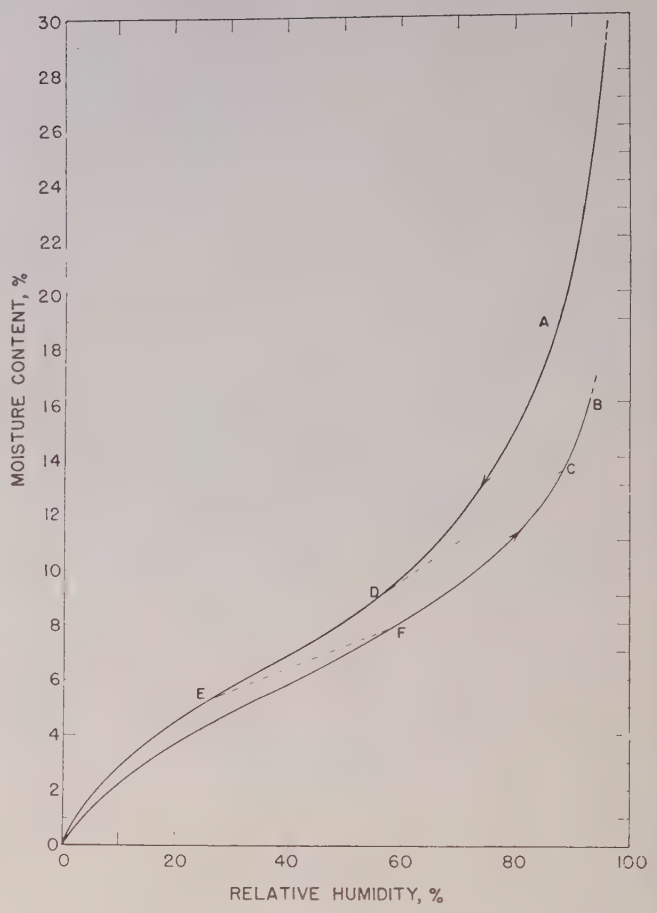


Fig. 1. Typical moisture sorption isotherms for pulp and paper

our general understanding of the moisture sorption characteristics of paper and paperboard.

Typical moisture sorption isotherms for pulp and paper are shown in Fig. 1. Briefly, on the basis of past studies, it is known that (1) for cellulosic materials that had never been dried, the first complete desorption curve A and the first complete absorption curve B define the outer boundaries of an equilibrium area; (2) the moisture contents, upon subsequent complete cycles in relative humidity, fall within the boundaries of this equilibrium area; (3) partial adsorption to a relative humidity corresponding to the point C, for example, followed by desorption, results approximately in the course shown by the dotted line CD and, similarly, partial desorption to the point E, followed by adsorption, results approximately in the course shown by the dotted line EF; (4) of the materials investigated, all exhibited sorption isotherms of similar sigmoid shape and displayed hysteresis; (5) the moisture content for most materials at a constant relative humidity varies inversely with temperature throughout the entire humidity range; and (6) at temperatures up to 100°C. and at constant relative humidity a linear relation exists between the logarithm of the moisture content and the reciprocal of the absolute temperature.

A study was made of the moisture content behavior of paper in the relative humidity range of 48 to 52% (the present range of TAPPI Standard T 402) and of the effect of humidity cycling on moisture content within the foregoing humidity range. These data were obtained in this laboratory and show the equilibrium moisture contents obtained by cycling the relative humidity over a small and carefully controlled range. The method used for obtaining the desired relative humidities was of the sweep-gas variety. A stream of air was saturated at the desired dew point temperature and then heated to the desired dry-bulb temperature; it then entered a

Table I. Moisture Content for Bleached Sulfite Pulp Handsheets Obtained by Humidity Cycling Between 48.0 and 52.4% R.H. at Temperature of 73°F.

Humidity cycle	*Moisture content, %*	
	52.4% R.H.	*48.0% R.H.*
1	8.37	7.89
2	8.12	7.83
3	8.04[a]	7.71
4	8.00	7.71
5	7.97	7.70
6	7.96	7.67
7	7.94	7.68
		(7.06% at 40.6% R.H.)[b]
		7.63
8	7.88	7.62
9	7.89	7.62
10	7.88	7.62
11	7.88	

[a] Because of an interruption in the flow of conditioned air, this is an interpolated value.
[b] Following seventh cycle, specimen was subjected to excursion in relative humidity to 40.6% and moisture content of 7.06%. Subsequently, it was successively exposed to 48.0 and 52.4% R.H. for four additional humidity cycles.
Moisture content based on equilibrium weight of specimen.

specimen chamber and was finally exhausted to the atmosphere. Close control of the dew point and dry-bulb temperatures and, consequently, the relative humidity (about ±0.1%), was accomplished with two thermostatically controlled baths. The bath controlling the dew point temperature was equipped with two thermoregulators, one being preset at a temperature to yield the lower of the desired two relative humidities and the other to yield the higher. Thus, a change from one relative humidity to another was accomplished by merely interchanging the two preset thermoregulators in the temperature control circuit. This procedure eliminated the danger of excursions beyond the desired humidity range. The specimen chamber was arranged so that weighings could be made with an analytical balance without removing the specimen from the atmosphere of the chamber. A specimen, weighing approximately 5 g., was used; for each cycle it was exposed to the respective relative humidities for a sufficient period of time to achieve constant weight.

The data given in Table I are for handsheets prepared from a bleached sulfite pulp that had never been dried. The first moisture content value of 8.37 appearing under the column heading 52.4% R.H., and corresponding to the first cycle, was approached from the wet state. Similarly, the first moisture content value of 7.89 appearing under the column heading 48.0% R.H., was approached by desorption from 52.4% R.H. Starting with the second cycle, and for the succeeding cycles, the moisture contents at 52.4% R.H. were obtained by absorption from 48.0% R.H. These conditions, it will be recognized, correspond to the drying of a handsheet in accord with TAPPI Standard T 205 in an atmosphere corresponding very nearly to the tolerance limits of TAPPI Standard T 402.

Upon examination of the data in Table I, it will be observed that the moisture contents, at the respective relative humidities, gradually moved in the direction of lower values and that, following an excursion of the specimen to a relative humidity of 40.6%, they remained constant for the remaining humidity cycles. The total change in moisture content occurring between the first and last cycles is 0.49% at 52.4% R.H. and 0.27% at 48.0% R.H. These changes in moisture content are not peculiar to the apparatus used for obtaining the data; they were confirmed by drying a duplicate set of handsheets, prepared from the same pulp, in the atmosphere of a room controlled in accord with TAPPI Standard T 402, and by weighing the specimen (specimen weight about 6 g.) as a function of the exposure time. The total change in moisture content in the atmosphere of the room and at the same relative humidity was 0.39 as compared to 0.38, the average of the foregoing changes. The reasons for the weight changes in the specimen, which resulted in the observed downward trend in moisture content, are not strictly known. However, it is speculated that they may be attributable to (1) a loss in volatile materials from the pulp, such as those responsible for the self-sizing properties of paper; (2) a decrease in the internal specific surface of the fibers and accessibility to moisture; or (3) an increase in degree of crystallinity.

Table II. Moisture Contents for Newsprint Obtained by Humidity Cycling Between 48.1 and 52.4% R.H. at Temperature of 73°F.

Humidity cycle	*Moisture content, %*	
	48.1% R.H.	*52.4% R.H.*
1	7.90	8.20
2	7.97	8.28
3	8.03	8.28
	(8.51 at 56.2% R.H.)[a]	
4	8.04	8.33

[a] Following third cycle, specimen was subjected to excursion in relative humidity to 56.2% and equilibrium moisture content of 8.51%. Subsequently, it was successively exposed to 52.4 and 48.1% R.H.
Moisture content based on equilibrium weight of specimen.

Table III. Moisture Content for 100% Rag Content Paper Obtained by Humidity Cycling Between 48.2 and 52.6% R.H. at Temperature of 73°F.

Humidity cycle	*Moisture content, %*	
	48.2% R.H.	*52.6% R.H.*
1	5.69	5.86
2	5.69	5.87
3	5.70	5.86
4	5.70	5.86
5	5.70	5.85
6	5.70	5.85
7	5.70	5.85
8	5.69	5.85
9	5.69	5.85
	(5.98 at 56.1% R.H.)[a]	
10	5.70	5.87
11		5.85

[a] Following ninth cycle, specimen was subjected to excursion in relative humidity to 56.1% and equilibrium moisture content of 5.98%. Subsequently, it was successively exposed to 52.6, 48.2, and 52.6% R.H.
Moisture content based on equilibrium weight of specimen.

Humidity cycling data for two samples of machine-made paper are given in Tables II and III. These were obtained by employing the same procedure used to obtain the data given in Table I, except that the sample of newsprint was first preconditioned at a relative humidity of 35% before exposing it to the cycling conditions, and the moisture content history of the rag content paper was unknown. Examination of these data reveal that the moisture content moved in the direction of slightly higher values during the several humidity cycles for the newsprint, and remained constant for the rag content paper. However, with respect to the newsprint, the total change in moisture content, occurring between the first and the last humidity cycles, was small and only 0.14% at 48.1% R.H. and 0.13% at 52.4% R.H.

Complete adsorption and desorption isotherms were also determined for the bleached sulfite handsheets and the two machine-made samples. Although these isotherms are not given here the slopes, in the humidity range of 48 to 52%, were determined, together with the slopes for the humidity cycling data. Because of the TAPPI tolerances, the values given in Table IV are the slopes multiplied by four. Here it will be seen that the slopes determined from the humidity cycling data are about one-half as large as those determined from the complete isotherms. This observation of a reduced slope, it will be shown later on, has an important bearing on considerations regarding the tolerances of the testing atmosphere and on the interpretation of data showing the dependence of physical properties on relative humidity.

For further consideration of the moisture content behavior of paper in a testing atmosphere controlled in accord with TAPPI Standard T 402, the foregoing data are utilized and the reader is referred to Fig. 2. The curves in this figure

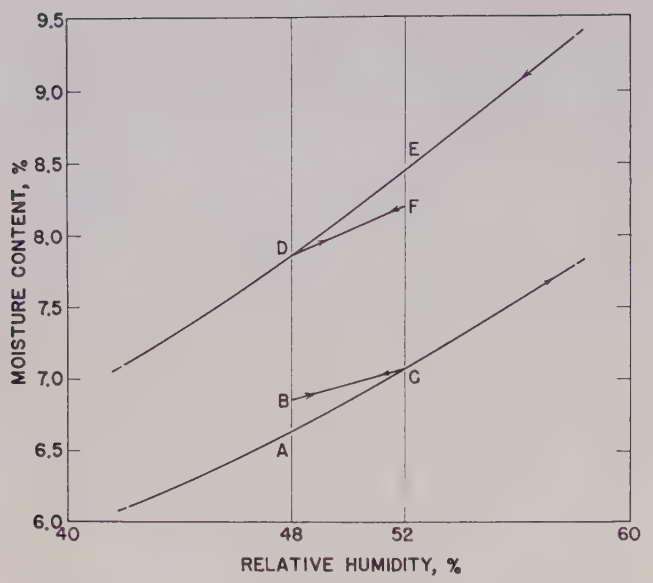


Fig. 2. Part of moisture sorption isotherm for pulp and paper

represent the center portion of the sorption isotherms shown in Fig. 1, with the curve segment DE corresponding to the curve A of Fig. 1 and the segment AC corresponding to the curve B of Fig. 1. The lines joining D and F, and B and C, are illustrative of the reduced slopes of the moisture content-relative humidity relationships resulting from humidity cycling.

For handsheets dried in the testing atmosphere, it may be noted in Fig. 2 that the moisture content under typical testing conditions will lie within the boundaries defined by EDF. In actual practice, however, there is only a remote possibility that the extreme difference in moisture contents, corresponding to the Points D and E, will be encountered because of fluctuations and/or cycling of the humidity in the atmosphere of the testing laboratory. The more likely situation is one wherein the moisture content will vary in accord with the slope of DF and be confined within the area EDF, although the lower boundary DF may shift downward. The latter situation would exist if there were a delay in testing and the moisture content drifted to a lower value as exhibited by the data shown in Table I.

For paper samples, preconditioned to a low relative humidity and then exposed to the testing atmosphere controlled in accord with TAPPI Standard T 402, the situation would be similar to that existing for the handsheet above but, in this case, the moisture content would vary in accord with the slope of BC and be confined within the area ABC.

For paper samples of unknown moisture content history, the moisture content, upon exposure of the samples to the testing atmosphere, could lie anywhere within the area defined by ADEC or, more likely, within the area BDFC and,

Table IV. The Effect on Moisture Content of Changing Relative Humidity from 48 to 52%

Sample	Change in moisture content, %: Based on desorption isotherm	Based on adsorption isotherm	Based on humidity cycling data	Ratio, column 4/columns 2 or 3
Bleached sulfite pulp handsheet	0.58		0.25[a]	0.43
		0.43	0.25	0.58
Newsprint	0.56		0.19	0.34
		0.40	0.19	0.48
100% rag content paper	0.40		0.16	0.40
		0.28	0.16	0.57

[a] This value is based on the data shown in Table I and it represents the average of the results for all cycles except the first. For the first cycle, the value at 52.4% R.H. was derived by desorption and it is therefore excluded from the average.

Table V. Percentage Change in Physical Properties Attributable to Change in Relative Humidity from 48 to 52%

Property	Change, % (12)	Change, % (13)
Basis weight	0.3	0.2
Bursting strength	1.0	0.6
Tensile strength, M.D.	2.3	1.3
Tensile strength, C.D.	2.5	1.0
Stretch, M.D.	4.6	1.5
Stretch, C.D.	5.4	3.1
Tearing resistance, M.D.	2.8	2.2
Tearing resistance, C.D.	...	2.6
Folding endurance, M.D.	17	...
Folding endurance, C.D.	13	...

M.D.—machine direction.
C.D.—cross direction.
Percentage change based on value of property at 50% R.H.
These changes are calculated on the basis of the slope of the relationship between the property and relative humidity, according to references (*12*, *13*).

for the reasons given above, would vary in accord with the slopes of DF and BC. The hysteresis effect, as it may be seen in this case, introduces a variable in moisture content which is much larger in magnitude than the variability resulting from fluctuations and/or cycling of the humidity in the testing atmosphere. Compared to the small effects attributable to the humidity variations in the testing atmosphere, hysteresis effects can readily account for differences in moisture content ranging from about 1.0 to 2.8% (*11*).

Among the several factors considered thus far, humidity cycling within the range 48 to 52% R.H., is the smallest contributor to variability in moisture content. Insofar as the moisture content is concerned, this variability is the only factor dependent upon the humidity and temperature tolerances of the testing atmosphere. The drift in moisture content, as shown by the data given in Table I, and the hysteresis effect are essentially independent of these tolerances and could be experienced even if the testing atmosphere were controlled to exactly 50% R.H. and 73°F. Fortunately, elimination of the hysteresis effect can be achieved by preconditioning the paper samples at either a high or a low relative humidity before exposing them to the testing atmosphere.

DEPENDENCE OF PHYSICAL PROPERTIES ON RELATIVE HUMIDITY

In order to determine the order of magnitude of the effect of relative humidity on the physical properties of paper within the relative humidity range from 48 to 52%, the data reported by Carson (*12*) and The Institute of Paper Chemistry as Instrumentation Studies XII (*13*) were used. The percentage change in the physical properties, based on the value of the property at 50% R.H., was calculated and these results are given in Table V. The data based on Carson's work represent the composite averages of eleven different samples (comprising book, writing, bond, ledger, index bristol, kraft, and rope manila); these were tested in the relative humidity range from 15 to 83%, starting with the lowest relative humidity (in order to eliminate the hysteresis effect) and then proceding with the conditioning and testing at intervals of about 15% R.H. The data based on the work reported in Instrumentation Studies XII represent the composite averages of 18 samples (comprising book, bond, ledger, index, manifold, mimeo, waxing, glassine, butcher's wrap, news, blotting, and jute tag); these were first preconditioned at 30% R.H. and then conditioned and tested at 40, 50, 65, and 75% R.H. in the order mentioned. Following this testing sequence, the hysteresis effect was studied; the samples were next conditioned at 85% R.H., but not tested, and then successively conditioned and tested at 75, 65, 50, and 40% R.H. However, the data given in Table V are based on the first testing sequence, wherein the moisture contents

Table VI. Percentage Change in Physical Properties Attributable to Hysteresis Effect at Relative Humidity of 50%

Property	Change, % (13)	Change, % (14)
Basis weight	1.4	1.0
Bursting strength	4.0	0
Tensile strength, M.D.	3.5	3.5
Tensile strength, C.D.	5.0	4.0
Stretch, M.D.	10.0	12.0
Stretch, C.D.	8.0	12.0
Tearing resistance, M.D.	6.0	7.5
Tearing resistance, C. D.	7.0	7.5

M.D.—machine direction.
C.D.—cross direction.

at the respective relative humidities were approached via adsorption from a lower value.

It is important to recognize that the data developed by Carson and The Institute of Paper Chemistry were obtained over a wide humidity range with the moisture contents at the respective relative humidities approached under conditions analogous to the obtaining of an adsorption isotherm. Accordingly, this means that the moisture contents, for these two cases, describe a curve paralleling curve AC of Fig. 2, and that the data given in Table V primarily reflect the changes that occurred in the properties as a result of moisture adsorption on going from 48 to 52% R.H. In the testing atmosphere, however, the situation is different; both adsorption and desorption are involved and, because of the humidity fluctuations and/or cycling, the moisture content would vary in accord with the reduced slope of curve BC, Fig. 2. Consequently, to the extent that the physical properties are linearly dependent upon moisture content (over small range in moisture content), it can be inferred from the data given in Table IV that the variability in the paper properties, attributable to humidity fluctuations of the testing atmosphere, will be smaller (approximately one half) than the values given in Table V. In other words, on the average, and with the exception of folding endurance, a variability ranging up to about 3% of the value of the property is attributable to the present humidity tolerance of TAPPI Standard T 402. It must be realized, of course, that there can be considerable variability between the response of individual papers and that the "average" itself is comprised of higher and lower values. Thus, there is a good possibility of encountering papers that may display a greater dependence on the humidity tolerance than indicated by the above average.

HYSTERESIS EFFECT

At least two studies have been made to determine the effects of hysteresis on the physical properties of paper—namely, Instrumentation Studies XII (*13*) and unpublished work carried out at The Institute of Paper Chemistry (*14*)—and the results of these are summarized in Table VI.

The data based on Instrumentation Studies XII were obtained in accord with the relative humidity sequence described in the previous section. Those based on the unpublished work represent the results obtained in the testing of five groups of randomized samples (comprising rag and sulfite bonds, groundwood, glassine, kraft, mimeo, unwaxed bread wrapper stock, waxed bread wrapper stock, and machine coated); these groups were preconditioned in accord with the following schedule: group 1 at 10% R.H. and 73°F.; group 2 at 27% R.H. and 73°F.; group 3 at 27% R.H. and 103°F.; group 4 at 68% R.H. and 73°F.; and group 5 at 85% R.H. and 78°F. Subsequently, each group was conditioned and tested in an atmosphere controlled in accord with TAPPI Standard T 402. Differences in physical properties between groups were calculated; these indicated that (1) the differences between groups 1 and 2 were small and insignificant, (2) the differences between groups 4 and 5 were also small but reflected the effects of the difference between the two preconditioning humidities (68 and 85%). A similar, but appreciably larger, effect on thickness, porosity, and surface properties, such as gloss and smoothness, was shown by Beckman, Denzer, and Sears (*15*), when using preconditioning relative humidities of 75 and 90%. (3) Employing an elevated temperature of 103°F. as a means for attaining a low relative humidity for preconditioning purposes appeared to have no serious detrimental effect upon the physical properties of group 3. However, caution should be exercised, when using high temperatures for preconditioning purposes, to avoid prolonged exposures, inasmuch as the aging of paper is accelerated at the higher temperatures. The major differences existed between groups 1 and 5, preconditioned at 10 and 85% R.H., respectively; the results for these, on a percentage basis, are given in Table VI. Here it may be seen that the hysteresis effect can be of an appreciable order of magnitude. Comparing the data given in

Table VII. Effect of Excursions to High and Low Relative Humidities on Tensile Strength, Stretch, Tensile Energy Absorption, and Zero-Span Tensile

Sample	Percentage increase, based on value at 50% R.H. — Tensile strength: After excursion to 78, 25 and 50% R.H.	Tensile strength: After excursion to 93, 25 and 50% R.H.	Stretch: After excursion to 78, 25 and 50% R.H.	Stretch: After excursion to 93, 25 and 50% R.H.	Tensile energy absorption: After excursion to 78, 25 and 50% R.H.	Tensile energy absorption: After excursion to 93, 25 and 50% R.H.	Zero-span tensile after excursion to 93, 25 and 50% R.H.
1-Sulfite, M.D.	−4	−3	5	7	0	3	2
2-Sulfite, M.D.	1	−1	1	6	2	5	2
3-Sulfite, M.D.	10	5	11	21	23	30	−1
4-Sulfite, M.D.	−3	−1	3	11	0	9	2
5-Sulfite, M.D.		−2		14		15	
Sulfite, C.D.		−3		6		2	
6-Linen writing, M.D.		5		32		41	
Linen writing, C.D.		−4		21		14	
7-Linen writing, M.D.		−6		15		6	
8-Linen writing, M.D.		−2		19		13	
9-Linen writing, M.D.		−3		11		6	
10-Rag bond, M.D.		−3		4		0	
Rag bond, C.D.		1		14		12	
11-Newsprint, M.D.		−3		−1		−4	
Newsprint, C.D.		0		12		13	
12-Onionskin, M.D.		−2		31		31	
Onionskin, C.D.		2		33		35	
13-Parchment, M.D.		4		19		20	
Parchment, C.D.		−2		5		−1	
14-Kraft, M.D.		3		13		18	
Kraft, C.D.		1		9		12	

M.D.—machine direction.
C.D.—cross direction.
Percentages given are relative to values obtained for samples preconditioned at 25% R.H. and conditioned and tested at 50% R.H. and 73°F. A minus sign preceding a given value denotes a decrease rather than an increase.

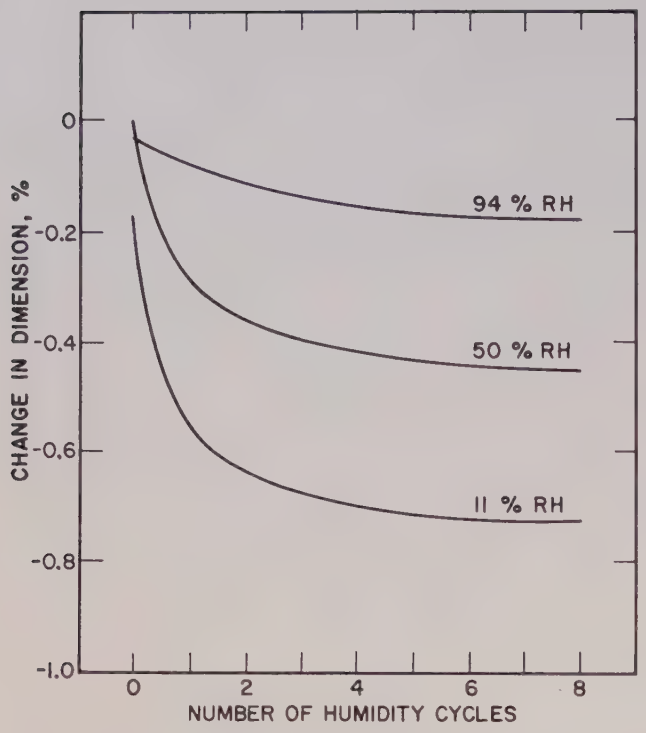


Fig. 3. Effect of repeated humidity cycling on the dimension of the paper—machine-direction

Table VI with those given in Table V it may also be seen that the hysteresis effect is several times larger than the effect of humidity cycling in the 48 to 52% R.H. range. This agrees favorably with expectations based on the moisture sorption data. Hysteresis effects are essentially eliminated in the laboratory by preconditioning the paper at 30% R.H., or lower, before conditioning and testing at 50% R.H. and 73°F.

HUMIDITY EXCURSION AND STRESS RELAXATION EFFECTS

The factors that have been considered thus far involved essentially the reversible effects of moisture content and/or relative humidity on the properties of paper. However, irreversible effects, resulting from an excursion of paper to a high relative humidity, are often observed. These can be of an appreciable order of magnitude, with the properties, in certain cases, altered to such an extent that they no longer characterize the original material. This effect evidently originates with the swelling and shrinking of the fibers and with the relaxation of dried-in or built-in stresses; the major effect occurs on the *first* exposure of paper to a high relative humidity, exceeding approximately 65%; it is dependent upon the extent of the excursion and it permanently alters such surface properties as gloss (*13, 15*) and smoothness (*15*), as well as dimensional and strength properties. These changes are nonrecoverable by manipulation of the moisture content or by preconditioning and conditioning the paper in accord with TAPPI Standard T 402.

Data showing the magnitude of the dimensional changes that can result from excursions to high humidities, and the effect of these excursions on tensile strength, stretch, tensile energy absorption (area under the load-elongation curve), and zero-span tensile strength, are given in Figs. 3 and 4 and Table VII.

The dimensional changes given in Figs. 3 and 4 for the machine and cross-machine direction of the paper, respectively, were determined with the Neenah multiple-specimen expansimeter (*16*) by exposing the specimens to relative humidities of 50, 11, 50, 94, and 50% at 73°F. in the order mentioned and in increments of about 15% R.H. The foregoing cycle was repeated for eight cycles and until no further significant changes occurred between cycles. Test spans of 10 in., corresponding to the first 50% R.H. condition, were used, and the percentage changes given in the figures are based on the initial 10-in. dimension.

The dimensional changes shown by the curves are for a sample of linen writing paper. Both directions of the paper, it will be seen, displayed appreciable shrinkage at the three levels of relative humidity. The machine direction curves reveal that the stress relaxation effect overshadowed the swelling effect to such an extent that all dimensions at 94% R.H. were smaller than the initial dimensions at 50% R.H.; this strong overpowering relaxation effect is not evident for the cross-machine direction even though the net shrinkage was greater. The machine direction shrinkage of slightly more than 0.7% and the cross-machine direction shrinkage of about 1.5% represent the maximum dimensional changes ever encountered in this laboratory in the testing of rag, newsprint, kraft, and sulfite papers. However, it is not uncommon to encounter samples that exhibit shrinkages approaching the values given above.

The data showing the irreversible changes that can occur in tensile strength, stretch, tensile energy absorption, and zero-span tensile strength, as a result of humidity excursions, are given in Table VII. To obtain these data, samples 1–4 were divided into three randomized groups and samples 5–14 into two randomized groups. For samples 1–4, group 1 was preconditioned at 25% R.H. and conditioned and tested at 50% R.H. and 73°F.; group 2 was preconditioned successively at 78 and 25% R.H. and then conditioned and tested at 50% R.H. and 73°F.; and group 3 was preconditioned successively at 93 and 25% R.H. and then conditioned and tested at 50% R.H. and 73°F. For samples 5–14, one randomized group was treated the same as group 1 above and the other the same as group 3. Hence, each foregoing group was tested under conditions wherein the 50% R.H. atmosphere was approached from a lower relative humidity and any changes occurring between groups of a given sample are therefore attributable to nonrecoverable effects and not to the hysteresis effect. The changes occurring as a result of the humidity excursions are given as percentages in the table and are based on the values obtained for the samples precon-

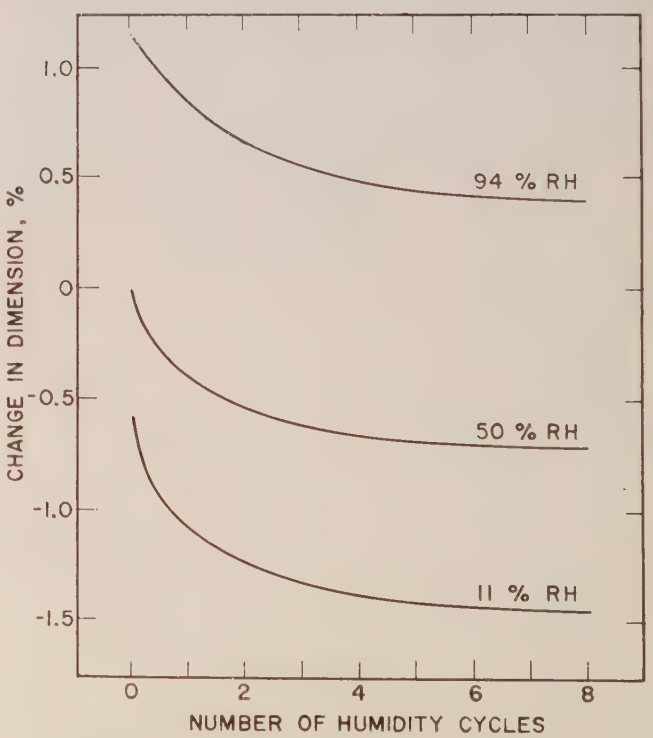


Fig. 4. Effect of repeated humidity cycling on the dimension of the paper—cross-machine direction

ditioned at 25% R.H. and conditioned and tested at 50% R.H. and 73°F.

The data given in the table reveal that humidity excursions, and the consequent stress relaxation effects, introduce changes that are relatively small for tensile strength and negligible for zero-span tensile strength. However, significant increments of the order of 30 to 40% may be seen for stretch and tensile energy absorption in the case of several samples.

The data given in the table reveal that humidity excursions, and the consequent stress relaxation effects, introduce significant changes in tensile strength, stretch, and tensile energy absorption, with the last two tests mentioned showing increments of the order of 30 to 40%. The zero-span tensile strength, which is a more direct measure of fiber rather than sheet characteristics, is seen to be negligibly affected by the humidity excursions. Compared to the variability of a few per cent introduced by the other factors considered thus far, the effects of humidity excursions and/or stress relaxation can be larger by several orders of magnitude. The magnitude of the humidity excursion and/or stress relaxation effect, it is emphasized, is entirely independent of the humidity and temperature tolerances of the testing atmosphere; the effect would exist even if there were no variability in the atmosphere of the testing laboratory. The potential magnitude of this effect lends emphasis to the *importance of maintaining control of the moisture content history of paper*, not only for the purpose of achieving good intra- and interlaboratory agreement, but for the purpose of properly characterizing the paper in a mill and its customers laboratory.

TEMPERATURE EFFECT

It appears to have been tacitly assumed over the years that temperature has a relatively insignificant effect on the physical properties of paper. Presumably, this assumption has been based on the observed relatively weak dependence of moisture content on temperature and, on inferences that the change in moisture content associated with temperature would exhibit only insignificant changes in physical properties. However, little work has been done to date to demonstrate the true and actual effects of temperature on the physical properties of paper and paperboard

Andersson and Berkyto (*17*), about a decade ago, reported the results of a study in which a machine-glazed kraft paper and a newsprint were used to determine the dependence of breaking stress and strain on temperature under conditions wherein the moisture content of the paper was held constant at

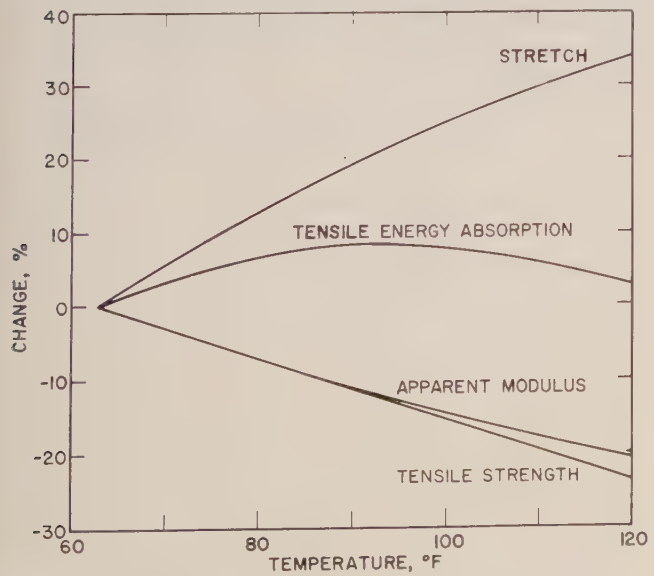


Fig. 5. Effect of temperature on physical properties of paper—at constant moisture content

Table VIII. Percentage Change in Physical Properties Attributable to Change in Temperature from 69.5 to 76.5°F.

	Sample	Change in property, %: Tensile strength	Stretch	Tensile energy absorption[a]	Apparent modulus
1.	Kraft, M.D.	−3.3	2.7	...	−3.0
	Kraft, C.D.	−3.8	8.2	...	−3.1
2.	Rag, M.D.	−3.0	4.7	...	−2.8
	Rag, C.D.	−3.1	6.4	...	−3.4
3.	Sulfite, M.D.	−3.0	2.0	...	−3.5
	Sulfite, C.D.	−2.9	4.1	...	−3.1
4.	Newsprint, M.D.	−3.1	1.5	...	−3.6
	Newsprint, C.D.	−3.1	2.4	...	−3.1
5.	Newsprint, M.D.	−3.3	1.2	...	−3.1
	Newsprint, C.D.	−3.0	4.6	...	−2.6
	Average, M.D.:	−3.1	2.4	0.6	−3.2
	Average, C.D.:	−3.2	5.1	4.3	−3.1

M.D.—machine direction.
C.D.—cross direction.
[a] Because of the potential error inherent in a curvilineal relationship based on three points, interpolated values for the individual samples are not given for this property.

essentially zero per cent. Calculations, based on the results of this work, show that the breaking stress and the strain (average for the two samples and directions) in the region of 73°F. were dependent on temperature to the extent of 0.26 and 0.09% per °F., respectively. Translating these values to the temperature range covered by the tolerances of the present TAPPI Standard, Andersson and Berkyto's results show a temperature dependence of 1.8 and 0.62%, respectively, for breaking stress and strain for a 7°F. change in temperature.

More recently, a temperature study of an exploratory nature, and similar in some respects to the foregoing, was made in this laboratory. However, in this study the moisture content was held at a constant value and at a level more nearly in accord with that obtaining in a standardized atmosphere of 50% R.H. and 73°F. For this study five different samples of paper (comprised of kraft, rag, sulfite, and two newsprints) were used and evaluated for tensile strength, stretch, tensile energy absorption, and apparent modulus of elasticity (slope of load-elongation curve within region of elastic limit) at temperatures of 63, 91, and 120°F. The samples were first preconditioned at 20% R.H. and 73°F. and then conditioned and tested at the designated temperatures; at each temperature a different relative humidity was used but the relative humidities were adjusted to achieve a constant moisture content level. Actual determinations indicated that moisture contents of 6.0, 6.3, and 6.2% were maintained, respectively, at temperatures of 63, 91, and 120°F.

The average results for the five samples and the two directions are given in Fig. 5, wherein the percentage change of a given property is based on the value of the property at 63°F. In this figure and for the temperature range of 63 to 120°F., it may be seen that appreciable changes of the order of 25, 35, and 20% occurred, respectively, in tensile strength, stretch, and apparent modulus, whereas the change in tensile energy absorption is comparatively smaller and of the order of a few per cent.

The magnitude of the temperature effect corresponding to the temperature range from 69.5 to 76.5°F. for the individual samples is given in Table VIII. Here it may be seen that the temperature dependence of the several physical properties ranges up to about 6% of the value of the property. By comparing these data with those given in Table V, it may be seen that the temperature effect corresponding to the present TAPPI tolerances is about the same order of magnitude as the relative humidity effect and, in fact, will be greater when account is taken of the effect of humidity cycling on the results given in Table V. One may infer from these data that more may be gained by tightening the tolerances on temperature than by tightening the tolerances on relative humidity. This is a fortunate and important result because good tem-

perature control is a necessary prerequisite to the achievement of good humidity control.

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DR. CLARK: Mr. Wink in your remark about the effect of temperature on the properties, I think perhaps it might give a different picture in that the temperature, if relative humidity is held constant, doesn't have that effect. Does not your chart show actual moisture content versus property?

MR. WINK: If one could hold the relative humidity constant while the temperature was varied, the changes in the physical properties would be less than if one held the moisture content constant and varied the temperature in the same way. We were trying to show the "pure" effect of temperature. One can not generalize about the constancy of relative humidity in a "conditioned" laboratory in which the temperature fluctuates. My charts show the relationship of the properties to temperature at constant moisture content.

DR. CLARK: If you let the temperature go up and down under constant humidity conditions then I don't think the effect of the temperature will be any where near as great as you indicate because if the temperature goes up and down with constant humidity the moisture content doesn't change very much.

MR. WINK: I agree that the affect of temperature on the properties is less when the relative humidity is held constant than when the moisture content is held constant. However, although the moisture content change with temperature at constant relative humidity is small, it is not negligible in its effect on the properties or the above statement could not be true.

DR. CLARK: However, this is a swindle because in the humidity room the moisture content doesn't change very much with temperature.

MR. WINK: I think we agree on what would happen under ideal conditions. We seem to differ in our expectation of what may happen in actual laboratories. If you have found an essentially negligible effect of temperature on paper properties I suspect that you have experienced a fortunate coupling of temperature and relative humidity fluctuations in the laboratory which provided unusually complete compensation of temperature and moisture content effects on the properties.

DR. CLARK: I leave this matter open to the house. I just want to point out that possibly there is a swindle in there anyhow. (Laughter)

MR. WINK: I have tried to separate the effects of moisture content and temperature. This was done to develop a better understanding of the problem and to provide a basis for deciding whether we needed to change the tolerance of the present TAPPI method.

DR. CLARK: But really in effect if in a constant humidity room the temperature fluctuates ±2°C., we will not have the effect that you are mentioning.

MR. WINK: You may have been fortunate in having data from laboratories in which the temperature and relative humidity fluctuations were so coupled that they jointly had a small affect on the properties. This good fortune may not be common. In some laboratories the temperature and relative humidity fluctuations may be so coupled that their joint effect on the properties is a maximum rather than a minimum.

DR. CLARK: The other point is that it is very interesting that the zero span test was unaffected by cycling up and down but the normal tensile test was. This is something also indicated in the previous paper—the effect of cycling being marked. I do not wish to get into a discussion of the fibrillation theory again, but am always looking for more evidence to show that the bonds are in fact caused by fibrils. The zero span tensile did not come down and there is no influence of bonding at all. The normal tensile came down greatly and I interpret that to mean that with increasing moisture the very finest fibrils would be wetted first and consequently lose their hold and with increasing moisture the coarser fibrils would become affected and, later of course, when the fibers themselves are wetted no strength would be left.

We have had two very interesting and provocative papers this morning and I am sure there must be a number of questions from the floor.

MODERATOR BIRDSALL: Are there any questions from the floor with regard to the last two papers?

MEMBER: I would like to clarify one point in my own mind. Your first graph, as I recall, showed the desorption and absorption isotherms for both pulp and paper and, did I understand you correctly in saying, that any further cycling would give you values within those—between those two curves? Is that correct?

MR. WINK: Yes. There are published data available which show for cotton and also for wood pulp that in the first desorption and the first absorption they establish the outer boundaries and then go from there on in. I believe, if I remember correctly, it takes perhaps six or seven cycles in relative humidity that are required before this thing here more or less repeats itself. In other words, actually, you narrow down in overall history the difference between the moisture content value at a given relative humidity for desorption and absorption.

MEMBER: And as you repeat the cycle, the curves approach one another—is that correct?

MR. WINK: Only to a small extent, and whatever changes occur, occur during the first several cycles.

MEMBER: The reason that I bring this up is that in some respects it seems a little contradictory with some data which this gentleman from IBM presented, where he repeated cycling, for example, over the card stock and you get a permanent change in the dimension of paper. And this suggests then that at least within limits the density of the paper,

the compactness of the structure has very little effect on its ability to absorb water at a given relative humidity, or am I drawing the wrong conclusion there?

The data would indicate, according to IBM work, that there is a permanent change in the structure of paper and that apparently this has very little effect on the ability of paper to absorb moisture.

MR. WINK: In working with handsheets prepared from different beating intervals, it has been our experience that the density of the paper and the compactness of the structure do not significantly affect the ability of the paper to absorb moisture at a given relative humidity.

DR. CLARK: In connection with that last question, you might remark upon the fact that the tensile very definitely drops off, which would indicate some irreparable damage to the bonding mechanism in the sheet. This would again indicate that some bonds are broken by being moistened and loosening. Would you agree?

MR. WINK: Yes.

MR. ACKERMAN (Union Mills Paper Co): Did the work that you did cover quite a range of papers in different grades?

MR. WINK: Yes, it covered several different kinds of paper.

MR. ACKERMAN: Did you include in these numerous grades any papers water finished on the machine—bring them over the dryers and then put them through a calender equipped with water boxes?

MR. WINK: I do not believe any were included.

MR. ACKERMAN: I was wondering whether or not you had used any of those, and if so, what effect would have shown.

MR. WINK: Rewetting and redrying the paper could introduce appreciable changes in the properties of the paper but whether or not the effects would be similar to those shown would depend on the final drying and winding conditions. Any built-in stresses prior to wetting would be essentially eliminated on wetting but, after wetting, calendering, tight draws and winding of the paper on the roll could reintroduce the built-in stresses. If the built-in stresses are not introduced again, after wetting, I would not expect the paper to display the effects that were shown in the tables. However, if the built-in stresses are introduced again then I would expect the paper to display the effect that I have shown.

MEMBER: Most of the papers this morning have been concerned with the effect of humidity on the physical properties of paper. However, has anyone done any work on the effect of relative humidity on printing properties? Most of the paper that were discussed will be used in the printing trades.

The Lithographic Technical Foundation published a paper about five years ago to show the effect of relative humidity on ink drying. They found it was quite significant. Has anyone any data to show the effects of relative humidity on printing?

MR. WINK: Yes, I believe that some work has been done in this area. ANPA reports contain information showing the effects of humidity excursions on thickness, gloss, smoothness, and porosity. Changes in these properties are pertinent to printing properties.

MR. DIXLER: The data showing the large effects of temperature at each constant moisture content, combined with your evidence to show that rate processes are involved in these permanent changes make me wonder whether there is evidence of either permanent effects or a least hysteresis effects due to temperature cycling. In particular, did you observe any evidence that the higher temperatures may lead to more rapid approach to permanent equilibrium?

MR. WINK: The question that you have raised is one that has been raised by a member of our staff. We would not be too surprised to find the existence of a temperature hysteresis effect. We are planning to conduct experiments in this area and at some future date we should have the answer to this question.

ROBERT RAGAN (Chicago Carton Co.): I would like to ask the last two speakers this question.

In collecting your data you have apparently gone to the full limits, from extremely dry to extremely wet conditions. Have you, in following the curve after exposure of paper to extremely wet conditions, interrupted the curve at, say, 40% R.H. and gone back again to the wet extreme to see if the hygroexpansivity now follows the path of the first curve?

We have done this and have found that apparently there is a different point of relaxation for different grades of paper. You may have to take one of them to only 85 to get permanent damage, and if you have reached that point, then the slope in going up or coming down in the center part of the relative humidity curve follows the same path.

MR. WINK: We do not have data showing what would happpen in this case. I would not expect the hygroexpansivity to retrace the same curve.

WALES H. NEWBY (Crown Zellerbach Corp): Most of the data there were concerned with tensile and stretch. If you have the data, what were the results of temperature on tear tests.

MR. WINK: We do not have data on the temperature effects.

ARTHUR J. FLINT (Buckeye Cellulose Corp): Mr. Wink, you stated that in the initial drying curve, after you had dried the samples for about 20 hr., they still continued to lose 0.4 or 0.5 of moisture, I believe?

MR. WINK: Yes, we observed a change in weight of this order of magnitude.

MR. FLINT: Then, if you condition a sample at a low level humidity and then return it to 50% do you find the same effect; that is, after it has been conditioned for several hours it still continues to change its moisture?

MR. WINK: I was referring to work that is now in progress. We are planning to take our present specimens to a low relative humidity and then back up to 50% R.H. At the moment I cannot answer your question.

DR. LASHOF: Mr. Callinan, in your expansivity measurements, after a few humidity cycles, six, seven, eight, you obtain an equilibrium. Is this really an equilibrium or does it just simply indicate that the limit of your measuring ability has been reached, or perhaps a limit of your patience in cycling? If you went on to 100 cycles, would you again find as much change as after the first six or seven?

MR. CALLINAN: I don't think you will have as much change as you have in the first six or seven cycles but I think it is wholly within the realm of possibility that you will have a different spectrum after doing it a hundred times than after doing it seven to 50 or 75 times.

Now, the reason I think so is that there are two variables the limits of which definitely affect the characteristics of the product when retesting. The humidity and the temperature can vary slightly. If then, on the hundredth cycle I do not have precisely the same temperature humidity characteristic that I had on the seventh, I am quite sure I will have created a new card.

MEMBER: In looking at your curve on the effect of temperature would it be safe to assume that the sheet of paper coming off the paper machine at very high temperatures would have a tendency to change, even to the extent of approximately 40 or 50%?

MR. WINK: I do not know for sure but I think that these curves would give a general idea of the magnitude of the changes that may occur upon going to very high temperatures.

MODERATOR BIRDSALL: I have a question to Mr. Callinan: We have been interested in curling properties of tabulating card stock and we have found that you can, depending on the kind of stock you have, get curl even when we fully condition at high moisture or at low humidity and some of the stock will have a reversal, will curl at both high and low relative humidity conditions. This generally is attributed to a given differential expansion or contraction on the two sides of the card, and I was wondering if in his analysis of expansion

and contraction data whether any consideration was given to this differential expansion and whether any effort has been made to measure the differential expansion and contraction on the two surfaces of the card?

MR. CALLINAN: Yes. Actually, this phenomenon of curl is a very, very important characteristic of tabulating stock. We now distinguish between permanent curl and temporary curl.

Permanent curl is I think understood to rise from a differential relaxation of the card. If you had a deck of cards stuck in a conventional sorter and suddenly subjected it to a change in humidity, you would find that one edge of our card was permanently shorter than the other edges, obviously the cards will curl. We have actually taken many decks of cards and deliberately put plastic gloves on the side of them in various positions and then run them through a few humidity cycles. You can make them curl up or down permanently. The only way that you can relieve the permanent curl would be to take all of the cards, subject them to say 97% R.H. and then dry them uniformly to a given equilibrium value.

ROY TRAVER (Union Bag Co.): As you dry the paper down to zero moisture content and bring it back to 50% R.H. it shows a wide gap in moisture content. Normally paper doesn't anywhere near approach the zero moisture content and I would assume that we would have a much less serious situation than was indicated by the hysteresis curve. Would you care to elaborate?

MR. WINK: Your assumption is correct. The maximum hysteresis at 50% R.H. is obtained for paper dried to a moisture content of 0%. If you dried the paper to a moisture content in equilibrium with 40% R.H., for example, and subsequently exposed it to 50% R.H., then the hysteresis at 50% R.H. would be smaller than the foregoing. As the other extreme, the minimum hysteresis at 50% R.H. would be displayed by a paper dried down to the equilibrium moisture content obtaining at 50% R.H.

DR. CLARK: I think, though, you would agree that when you come down to a reasonable level, say below 30, that you pretty well get back on the absorption track.

MR. WINK: Yes.

DR. CLARK: I think we have had a very interesting discussion and I am sorry that time is so short. We had better pay more attention to the effect of temperature. I think you will agree with me that this morning's discussion has been very enlightening. I wish to thank all of the gentlemen present for participating in it and we will now recess for lunch.

Wednesday Afternoon Session—Sept. 28, 1960

The session was reconvened at 2:10 o'clock p.m., T. W. Lashof opening the session.

DR. LASHOF: Gentlemen, the meeting will please come to order.

We have two groups of papers on this afternoon's session of the symposium on relative humidity and paper test methods. The first group is on the measurement of relative humidity and the second group is on the design and control of conditioning and testing rooms.

Your chairman and moderator this afternoon will be D. Noel Obenshain of West Virginia Pulp and Paper Co. Mr. Obenshain is chairman of the TAPPI Testing Division's Technical Services Group. The Physical Methods Committee of this group is beginning a major investigation into the subject of this symposium.

I now turn the meeting over to Mr. Obenshain.

MODERATOR OBENSHAIN: Thank you, Ted. Members and friends of TAPPI, I am sure all of you learned a great deal about the effect of relative humidity on the properties of paper and paperboard this morning. Some of these discussions were quite enlightening, others left us with questions still hanging.

Those of us who have anything at all to do with humidity rooms certainly wonder how you measure humidity accurately and, the other thing, even if you measure it, how do you maintain a constant humidity room at constant humidity. I hope that the discussion we shall have this afternoon will throw some light on this subject. I hope that it will help us all do a better job in our plants and laboratories in this matter of relative humidity.

Our first paper has to do with standards in the establishment of relative humidity. I understand that the correct title of this paper is simply "Humidity Standards." This paper will be given by A. L. Wexler, who is chief of the Mechanical Instrument Section of the National Bureau of Standards. Mr. Wexler is a member of a number of scientific societies—the Instrument Society of America; the American Meteorological Society; the American Society for the Advancement of Science; and also the Washington Academy of Sciences. He has his degree from the College of the City of New York.

I now present to you Mr. Wexler who will present his paper.

Humidity Standards*

ARNOLD WEXLER

This paper describes and discusses instruments which may serve as primary and secondary humidity standards, including a gravimetric hygrometer, now under development at the National Bureau of Standards, to serve as its basic reference for humidity measurements. The use of precision humidity generators for producing atmospheres of known humidity is outlined. Methods and techniques of obtaining fixed humidity points are given.

A VARIETY of instruments are used in the measurement of the moisture content of gas. Many of these are purely empirical and require testing and calibration. Some instruments have a theoretical basis. Even these sometimes require calibration for the highest accuracy. Then, too, instruments operating on different principles, and, occasionally, instruments operating on the same principle will yield divergent results. A method of test or calibration, or a standard against which other instruments may be compared, is necessary if consistent and accurate measurements of humidity are to be made.

The testing and calibration of hygrometers may be approached in either of two ways. An instrument or method that has a firm theoretical basis and is capable of giving highly accurate and reproducible absolute measures of the moisture content of gas may be chosen as a standard. Hygrometers may then be calibrated by direct comparison with the standard when simultaneously exposed to various humidities. Alternatively, atmospheres of known humidity may be produced and controlled. Hygrometers may then be exposed to the known atmospheres, or, the gas of known humidity may be fed to the instruments under test.

HYGROMETER STANDARDS

Primary Standard

The gravimetric method of water vapor measurement is generally considered the most precise and accurate in hygrometry. In this method, the mass of water vapor admixed with a volume of gas is absorbed by a desiccant and then the volume of the dry gas is measured directly. Since these quantities are fundamental, this method yields an absolute measure of humidity. Because of this, and its relatively

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* The contents of this paper are in large measure based on NBS Letter Circular LC 1026, dated April, 1957.

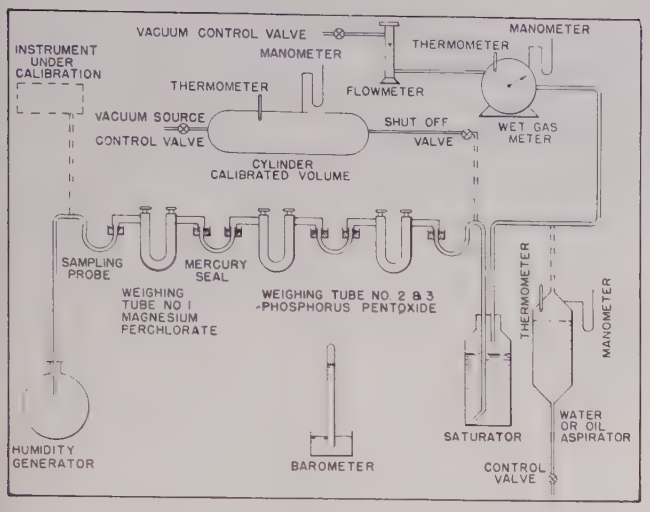

Fig. 1. Gravimetric method of moisture measurement

great inherent accuracy, the gravimetric method is often used as a primary standard against which other methods and instruments are compared. However, to achieve the inherent accuracy of the gravimetric method there must be careful attention to details. Measurements are time consuming, especially those involving low moisture contents. The results are average values. Hence it is usually necessary, when calibrating other instruments against the gravimetric method, to employ a humidity generator that produces air of constant humidity. This method is principally used for research work of the highest accuracy or for making fundamental calibrations.

The gravimetric method has a long and well established history of use. In 1845, Regnault (*1*) employed it to determine the density and vapor pressure of saturated water vapor in air. Subsequently, in 1888, Shaw (*2*) repeated some of Regnault's work as part of an extensive investigation on the hygrometric methods in use at that time. Awberry (*3*) utilized it to measure the water content of saturated air at elevated temperatures while Awberry and Griffiths (*4*) used it as a standard for low temperature calibrations. Bartlett (*5*) and Saddington and Krase (*6*) measured the water content of gases saturated at high pressures with the gravimetric method while Goff, *et al.* (*7,8*), utilized it to determine the interaction constant of moist air. Walker and Ernst (*9*) and Wexler (*10*) have utilized this method for calibrating and checking the accuracy of precision humidity generators. It has also been used extensively in investigations of the vapor pressures of liquids and solutions, particularly salt solutions (*11–24*).

An experimental setup for making a moisture determination with the gravimetric method is shown in Fig. 1. Gas of constant water vapor content is issued from a humidity generator and a sample withdrawn through an absorption train, saturator and laboratory wet gas meter, etc. The moisture is absorbed by the train of U-tubes. The first U-tube removes all, or nearly all, of the water. If the absorbent in the first U-tube is near exhaustion or if the gas flow is too rapid some moisture may remain in the effluent gas. The second tube will remove the amount that is still left. The third U-tube serves as a guard to prevent water vapor from diffusing back from the saturator or gas meter. The first two tubes are weighed before and after a run to give the mass of water vapor removed from the air. The volume of dry gas emerging from the absorption train is measured by a laboratory wet gas meter. The gas meter, however, saturates the gas that flows through, so that the indicated volume is that of moist air (*28*). To insure that the gas is completely saturated before entering the gas meter so that no changes in water level will occur due to evaporation, a saturator is inserted immediately upstream of the gas meter. This saturator may be a container or, preferably a series of containers, filled with water-washed gravel or pumice moistened with water. Since the gas meter measures the volume of saturated gas the indicated volume must be corrected to give the volume of dry gas associated with the absorbed water vapor. The mass of dry gas is obtained by multiplying the volume by the density.

The absolute humidity, r, in terms of mass of water vapor/unit mass of dry gas, is given by

$$r = \frac{M_w}{Vc\left(\frac{\rho}{1 + 0.00367t}\right)\left(\frac{P - e_s}{760}\right)} \qquad (1)$$

where

M_w = mass of water vapor absorbed in the first two U-tubes, g.
V = indicated gas meter volume, cu. cm.
c = calibration factor for gas meter (a function of rate of flow)
ρ = density of dry gas at standard pressure and temperature (760 mm. Hg and 0°C.)
t = temperature of the gas in the gas meter, °C.
P = absolute pressure of the gas in the gas meter, mm. Hg
e_s = saturation vapor pressure at temperature t, mm. Hg

The procedure in making a run is as follows: The test gas is drawn through the absorption train, saturator, gas meter, and flowmeter. The rate of flow is adjusted and controlled at a constant value by the vacuum control valve. After a predetermined volume of test gas has been sampled, the control valve is closed, the absorption tubes sealed and the change in weight of U-tubes nos. 1 and 2 is determined.

Although this procedure appears to be simple, certain precautions should be observed to reduce and eliminate sources of error. A constant rate of flow should be maintained through the system. The wet gas meter is flow-dependent so that the calibration constant (c in equation (1)) will depend on the flow. The rate of flow should be kept low, preferably below 1 l.p.m., if complete absorption of the water vapor from the sample gas is to be assured. U-tube no. 1 is filled with anhydrous magnesium perchlorate, $Mg(ClO_4)_2$, while no. 2 and no. 3 are filled with phosphorous pentoxide, P_2O_5. Anhydrous magnesium perchlorate is a granular material with an excellent drying efficiency (*25, 26*), and is easy to handle, while phosphorous pentoxide, which has the greatest known drying efficiency (*27*), is a powder that readily deliquesces and must be handled with care. In filling the absorption tubes, the desiccant should be packed loosely so that no appreciable pressure drop is introduced. Furthermore, it is desirable to insert glass wool plugs at intervals between the desiccant to avoid channeling of the gas on passage through the tubes. It is well to remember that the maximum permissible pressure drop across a wet gas meter is about 0.3-in. water. A greater pressure differential may blow the water seal in the meter, causing gas to by-pass the measuring compartments. Furthermore, the typical gas meter is a low pressure device, built for operation at a differential of a few inches of water pressure with respect to ambient pressure. Excessive pressures may distort the case, cause the shaft stuffing box to leak, and produce a bind on the drum thereby affecting the meter accuracy. The gas meter must be carefully leveled, the water level properly adjusted, and only integral revolutions used as a measure of the volume (*29, 30*).

In making precision weighings of the absorption tubes such factors as buoyancy, change in weight of the internal gas volume, change in external surface conditions, static change, and thermal gradient within the balance case, contribute errors that may be easily overlooked. The use of an identical dummy absorption tube as a tare will tend to compensate for buoyancy. If this tare is treated and handled in a similar fashion as the tubes in the absorption train, then some of the other errors may be reduced. The internal pressure within

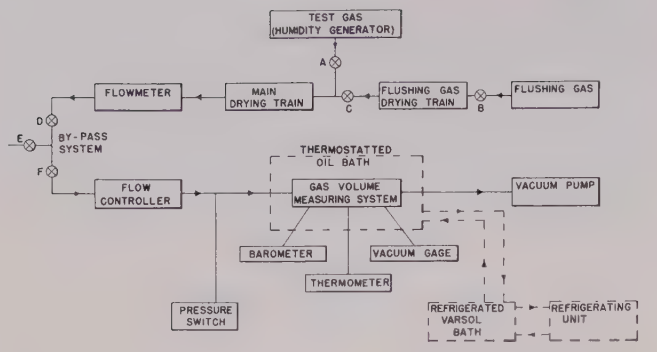

Fig. 2. Block diagram of NBS gravimetric hygrometer

the tare is adjusted to that within the test absorption tube by momentarily opening it at the same time that the latter is being sealed for weighing. The tare and main tube should never be handled with bare hands, for moisture and oil from the hands will affect the weight. Both may be wiped with a damp cloth to remove static charge prior to insertion into the balance case. One technique for insuring that the balance pans do not accumulate static charge is to keep an ionizing source (e.g., a radioactive salt) within the case. Furthermore, the balance should be in a room that is maintained at a fairly constant temperature and where there are no sources of heat radiation that could induce temperature gradients, and hence convection currents, within the case. The relative humidity within the balance case should be constant, for changes in humidity may shift the balance rest point.

It is important that no hygroscopic materials be used in the experimental setup other than the drying agents in the absorption train. Rubber and some plastics, for example, are sufficiently hygroscopic as to act as moisture sources and sinks. For this reason, tubing and stoppers fabricated from such materials must not be used. The setup should be made from glass or glass and metal. Seals, such as on the absorption tubes, are achieved with ground glass stopcocks. Pneumatic connections between components may be made through mercury seals or O ring seals. Every effort must be made to eliminate the possibility of error from moisture sources or sinks.

A typical absorption tube weighs about 70 g. The duration of a gravimetric determination can be adjusted so that at least 0.2 g. of water is absorbed. An analytical balance, with a capacity of 200 g. and a sensitivity of 0.1 mg. will weigh the absorbed water vapor with sensitivity of 1/2000. Assuming that all precautions with regard to buoyancy, etc., have been taken, an accuracy in weighing of 1/1000 may be expected. If more water is absorbed greater accuracy may be obtained.

The accuracy of measurement of volume with the gas meter is limited at best to 1/500 (*29*, *30*). The pressure measurement can be made with an accuracy of at least 1 mm. Hg and the temperature measurement can be made

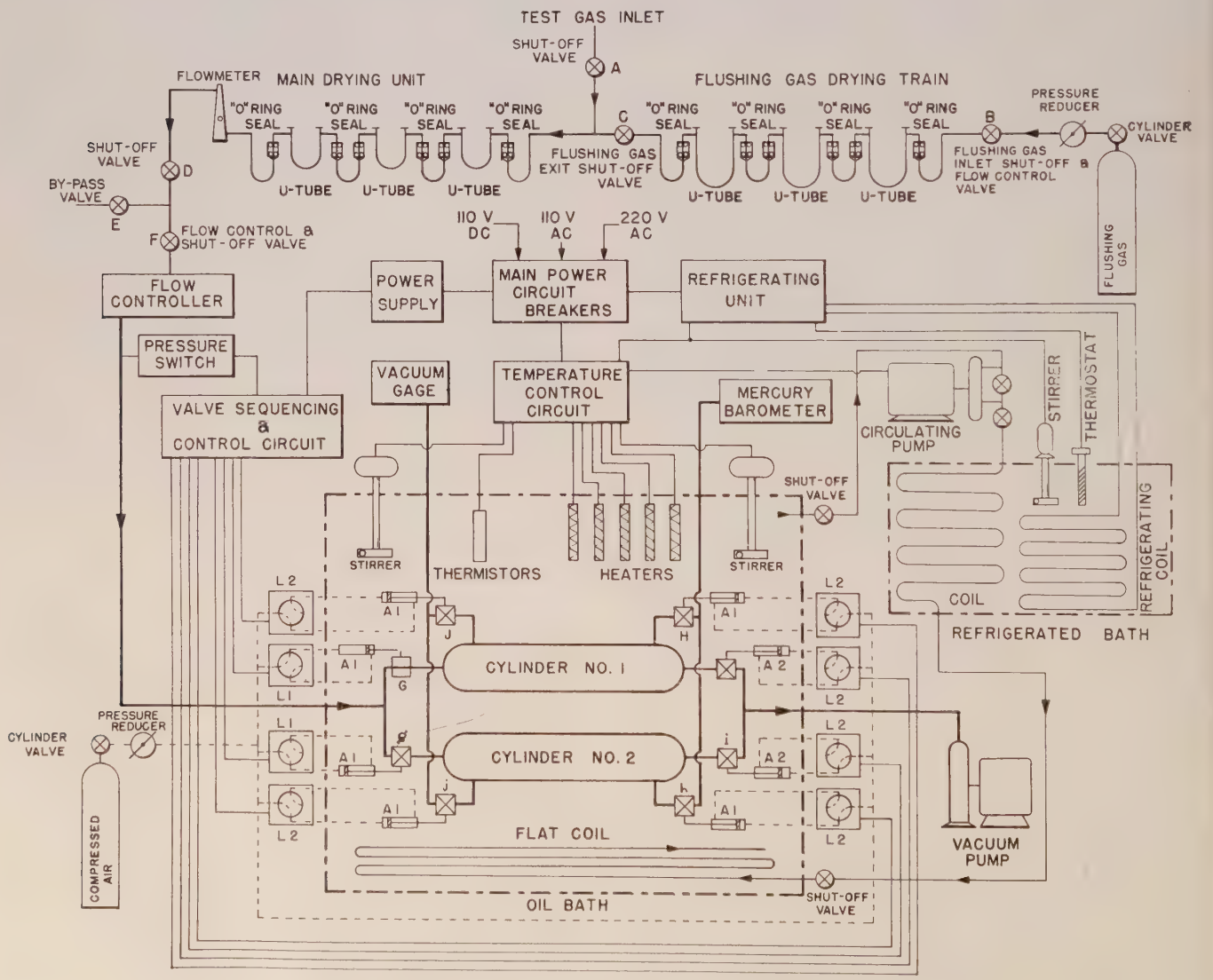

Fig. 3. Flow diagram of NBS gravimetric hygrometer

better than 0.1°C. Thus these two measurements will be better than about 1/760.

It is apparent that the overall accuracy is limited by the volume measurement. If a greater overall accuracy is required a water aspirator can be substituted for the gas meter. A further refinement would be to use an oil aspirator. If an oil with negligible vapor pressure is chosen (say butyl phthalate) then the saturator may be eliminated too. In that case, equation (1) becomes

$$r = \frac{M_w}{V\left(\frac{\rho}{1 + 0.00367t}\right)\frac{P}{760}} \qquad (2)$$

The National Bureau of Standards has developed a gravimetric hygrometer to serve as its primary standard for humidity measurement. Figure 2 is a block diagram and Fig. 3 is a flow diagram of this hygrometer. It consists of a solid desiccant absorption train (main drying train), a gas volume measuring system, a vacuum pump, temperature and pressure measuring instruments, and suitable valves and controls. The test gas is continuously withdrawn at a nominally constant flow rate from a humidity generator, passes through the main drying train and gas volume measuring system and discharges to the vacuum pump. The gas volume measuring system comprises two calibrated stainless steel cylinders, each with a nominal internal capacity of 30 l., immersed in a thermostatted oil bath. Through the proper sequencing of the on-off position of valves attached to the inlet and exit ports of the cylinders, by means of a pressure switch and valve sequencing and control circuit, each cylinder is alternately evacuated and filled with the test gas to a predetermined pressure. The internal capacity of each cylinder, together with the pressure and temperature of the gas therein, provide a highly accurate measure of the gas volume. The total gas volume is the sum of the individual fillings of each cylinder.

The gravimetric method yields a measure of the humidity in terms of mixing ratio. Two fundamental quantities are determined directly: the mass of water vapor and the volume of dry gas. The latter, through the known density of the test gas, is converted into mass of gas. Thus, the value of the moisture content of the gas has been obtained in terms of an absolute definition by direct measurement. By recourse to the laws of gaseous behavior it is possible to convert from mixing ratio to such terms as vapor pressure, specific humidity, relative humidity or saturation deficit. However, the accuracy with which the humidity can be expressed in units or terms derived from the mixing ratio is limited by the degree of validity of the laws of gaseous behavior and vapor pressure. The accuracy with which the mixing ratio can be determined directly is limited only by the accuracy of the measurement of fundamental quantities.

With the Bureau's gravimetric hygrometer, an attempt is being made to measure the various parameters that determine the mixing ratio with an accuracy of 1/10,000 with the expectation that the mixing ratio itself will thus be known to 1/1000.

Secondary Standards

The time, work, painstaking care, and skilled personnel required for setting up and using the gravimetric method preclude its general use except for fundamental calibration work. There is a need, therefore, for one or more types of instruments that could serve as secondary or working standards. The secondary standard is one which can be calibrated against the primary standard and then, in turn, used for routine calibrations. It would appear that to be acceptable as a secondary standard an instrument should directly measure the humidity of the air in terms of fundamental quantities, or should have a firm theoretical basis for its operation so that its indication can be related to the humidity through known physical laws. It is intended, at the National Bureau of Standards, to investigate for possible use as secondary standards such instruments as the dew-point hygrometer, the microwave hygrometer, and the psychrometer.

PRECISION HUMIDITY GENERATORS

Several convenient and practical methods are available for producing atmospheres of known humidity with sufficient precision and accuracy that the use of auxiliary hygrometers for direct measurement is not required. Equipment incorporating these methods may be called precision humidity generators.

Pressure Humidity Apparatus

In this type of apparatus, a stream of air at an elevated pressure is saturated and the pressure of the saturated air is reduced as required to give any desired humidity. If the temperature is held constant during saturation and after expansion, and the perfect gas laws are obeyed, then the percentage relative humidity, RH, at the lower pressure, P_t, is the ratio of the absolute values of the lower pressure, P_t, to the higher pressure, P_s, that is,

$$RH = \frac{P_t}{P_s} \times 100 \qquad (3)$$

Water vapor-air mixtures depart from ideal gas behavior. Furthermore, air, when saturated with water vapor at high pressures, does not hold the same amount of moisture as at atmospheric pressure (*5*, *31*). Equation (3), therefore, does not strictly define the relative humidity, particularly at high values of P_s. Weaver (*32*, *33*) has shown that an empirical equation of the form

$$RH = 100 \times \frac{P_t\,(1 - KP_t + K'P_t^2)}{P_s\,(1 - KP_s + K'P_s^2)} \qquad (4)$$

more closely yields the true relative humidity where the constant K has a value of 1.9×10^{-4} and K' is equal to 1.4×10^{-8} when the pressure is expressed in pounds per square inch. The magnitude of the ratio $(1 - KP_t + K'P_t^2)/(1 - KP_s + K'P_s^2)$ does not differ from unity by more than $^1/_4$ of 1% when P_t is at atmospheric pressure and P_s is no greater than 150 p.s.i.a. For these pressures, the relative humidity will be in the range of 10 to 100%.

The pressure method was used by Weaver and Riley (*32*) for the calibration of electrically conducting hygroscopic films employed in the measurement of water vapor in gases. Their equipment was designed for low rates of gas flow and was used under room-temperature conditions. Wexler and Daniels (*34*) used the two-pressure principle in the design of a precision humidity generator that produced atmospheres

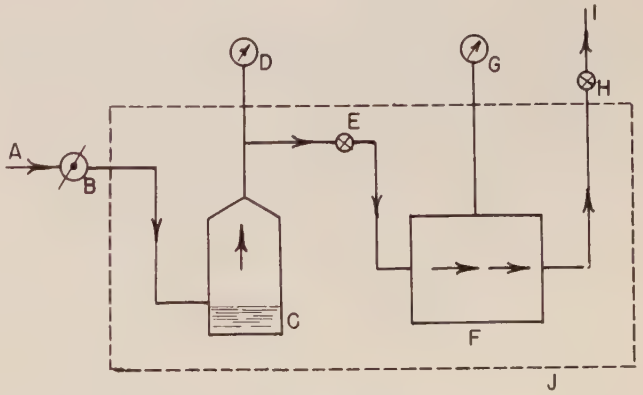

Fig. 4. Simplified schematic drawing of pressure humidity generator

A. Source of high pressure air. B. Pressure regulator. C. Saturator. D. Precision pressure gage. E. Expansion valve. F. Test chamber. G. Precision pressure gage. H. Control valve. I. Atmosphere or vacuum source.

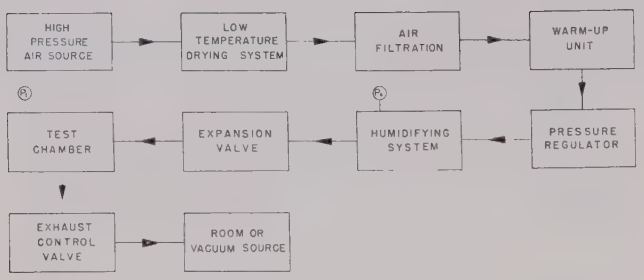

Fig. 5. Block diagram of NBS pressure humidity generator

of known relative humidity from 10 to 98% over a temperature range from −40° to +40°C. with an accuracy to within $^1/_2$ of 1% R.H., or better.

Figure 4 is a simplified schematic drawing illustrating the principle of operation of the apparatus, while Fig. 5 is a block diagram and Fig. 6 a schematic of a practical version of the apparatus. The apparatus is a continuous-flow device. Air from a high-pressure source is dried and cleaned by a low-temperature drying and filtering system. It is then heated in a warm-up unit prior to entering the humidifying system. Two pressure regulators in series reduce and control the pressure in the saturators at any desired value. After emerging from the humidifying system, the air passes through an expansion valve into a test chamber, where its pressure is maintained constant, usually at atmospheric pressure, and then allowed to exhaust into the room or a vacuum source. The drying and filtering systems are immersed in a bath of dry ice and Stoddard's solvent. The humidifying system, expansion valve and test chamber are immersed in a thermostatted bath whose temperature can be controlled at any desired value.

Instruments undergoing test or calibrations can be inserted into the test chamber or, alternatively, air from the test chamber can be fed to the test hygrometer. Provided one can assure complete saturation, the accuracy with which the pressure humidity apparatus can generate air of known relative humidity is limited by (1) the accuracy with which the pressure is measured, (2) the uniformity or constancy of the temperature from the final saturator through to the test chamber, and (3) the degree of validity of the correction term of equation (4). By using suitable pressure measuring instruments, the accuracy of the pressure measurements can be made to 1 part in 500. The temperature can be held constant to at least 0.05°C. The correction term can be determined, by the gravimetric method, with corresponding accuracy. It is estimated that the pressure humidity apparatus will produce a relative humidity that is known to within $^1/_2$ of 1% R.H., or better.

The question may arise as to whether complete saturation is obtained. This can be ascertained by a simple experiment. The apparatus has an external saturator which can be charged with water and operated at any desired temperature, or it can be maintained dry. If this external saturator is maintained dry, then the humidifying system within the thermostatted bath must provide all the moisture necessary to saturate the air at the bath temperature. The apparatus is operated, therefore, with the external saturator dry and the moisture content is measured by inserting a precision hygrometer in the test chamber, or by sampling the air and making a gravimetric determination. Water is added, now, to the external saturator and its temperature is adjusted to some value above that of the thermostatted bath. Without changing any other operating conditions, air is passed through the apparatus. Since the external saturator supersaturates the air with respect to bath temperature, the humidifying system within the thermostatted bath precipitates and condenses out the excess water. The moisture content is measured again and compared to the previous measurement. If the two are identical, they give sufficient assurance that complete saturation is obtained.

Basically, this equipment generates a known relative humidity. From a measurement of the temperature and pressure within the test chamber and with the application of the gas laws and the saturation vapor pressure of water the relative humidity can be converted to other units of humidity measurement.

Two-Temperature Humidity Apparatus

The method employed in this apparatus for producing atmospheres of known relative humidity is to saturate a stream of air with water vapor at a given temperature and then to raise the temperature of the air to a specified higher value. If t_s is the temperature of saturation, e_s the saturation pressure of water vapor at temperature t_s, t_t the elevated temperature, and e_t the saturation pressure of water vapor at temperature t_t, then the relative humidity, RH, at temperature t_t is

$$RH = \frac{e_s}{e_t} \times 100 \qquad (5)$$

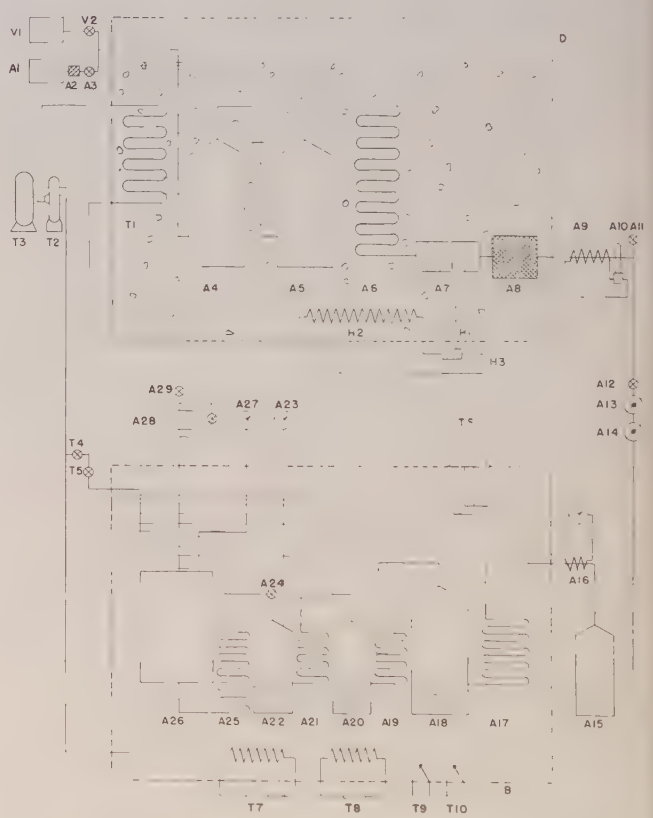

Fig. 6. Schematic drawing of NBS pressure humidity generator

A1, High pressure source. A2, Filter. A3, Valve. A4, Centrifugal water separator. A5, Centrifugal water separator. A6, Copper cooling coil. A7, Fin air drier. A8, Low temperature filter. A9, Electric heater. A10, Bimetal thermoregulator. A11, Air reversal valve. A12, Shut-off valve. A13, Pressure regulator. A14, Pressure regulator. A15, External gross saturator. A16, Resistance thermometer and indicator. A17, A19, A21, A25, Copper coil heat exchangers. A18, A20, A22, Centrifugal saturators. A23, A27, Pressure gages. A24, Expansion valve. A26, Test chamber. A28, Linear flowmeter. A29, Exhaust control valve.

B, Insulated liquid (varsol) constant temperature bath.

D, Insulated dry ice bath.

H1, Bimetal thermoregulator. H2, Electric heater. H3, Input voltage.

T1, Varsol cooling coil. T2, Positive rotary displacement pump. T3, Motor. T4, Varsol by-pass valve. T5, Varsol control valve. T6, Centrifugal stirrer. T7, Constant electric heater. T8, Intermittent electric heater. T9, T10, Thermistors.

V1, Vacuum source. V2, Vacuum shut-off valve.

In equation (5), the assumption is made that the absolute pressure of the air at the elevated temperature, t_t, is the same as the absolute pressure of the air at the saturation temperature, t_s. If these two pressures are not identical, then a pressure correction must be introduced. If P_s is the absolute pressure of the air at t_s, and P_t is the absolute pressure of the air at t_t, then the relative humidity is

$$RH = \frac{e_s}{e_t} \times \frac{P_t}{P_s} \times 100 \qquad (6)$$

The inherent accuracy of this method depends not only on the accuracy with which the temperatures and pressures are measured, but also on the completeness of saturation and on the degree of accuracy or validity of the temperature-vapor pressure relationship for water. The latter may be considered to have been established with sufficient exactness for most purposes in hygrometry (*35*, *36*). Both the temperature and pressure can be measured to an accuracy of at least 1/1000. The completeness of saturation can be assured by employing a recirculating scheme. Thus this method has considerable inherent accuracy. Its main limitation is the time required for changing from one relative humidity to another, for this involves a temperature change.

The two-temperature principle has been used successfully in research laboratory equipment. Shaw (*2*) used it in a laboratory setup for investigating the performance of hygrometers. Wiegerink (*37*) constructed equipment, based on this principle, for conditioning materials at constant humidities and elevated temperatures. Wexler (*38*) developed an apparatus capable of producing any desired relative humidity over a wide range of temperatures. Burcham (*39*) described a humidity oven, operating over the temperature range of 30 to 100°C., in which he achieved relative humidities of 30 to 95%.

A simplified schematic diagram illustrating how the two-temperature method may be employed on an apparatus is shown in Fig. 7. By means of a gas pump, air is circulated from a saturator into a test chamber and then back into the saturator. The temperature, t_s, of the saturator and the temperature, t_t, of the test chamber are maintained at the respective desired values by thermostatted baths. Complete saturation is achieved simply and efficiently by recirculation of air over water (or ice) in the saturator, in a closed system. Once equilibrium has been established the saturator does not have to change the absolute moisture content of the recirculated air but only to maintain it.

The design of a practical system, based on this method, is shown in Fig. 8. It differs from the elementary design of Fig. 7 in that the test chamber temperature is controlled by means of a heater inserted in the air stream rather than by immersing the test chamber in a thermostatted bath. The elimination of a thermostatted bath for the test chamber, with the resultant simplification in design and construction, is made possible by the fact that the saturator must necessarily be maintained at a lower temperature than the test chamber, and hence the only requirement for achieving any desired test chamber temperature is the introduction of the requisite amount of heat into the air stream.

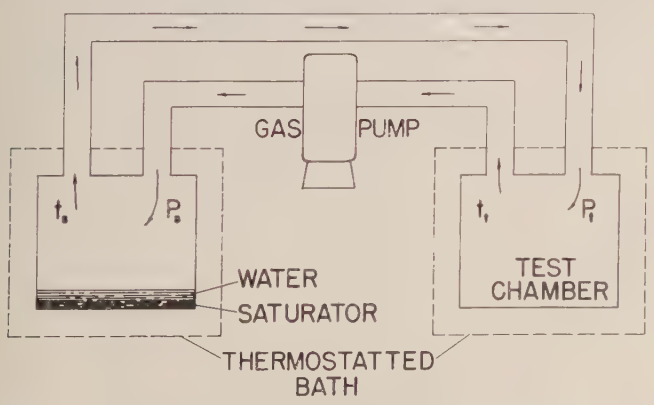

Fig. 7. Simplified schematic drawing of two-temperature humidity generator (1)

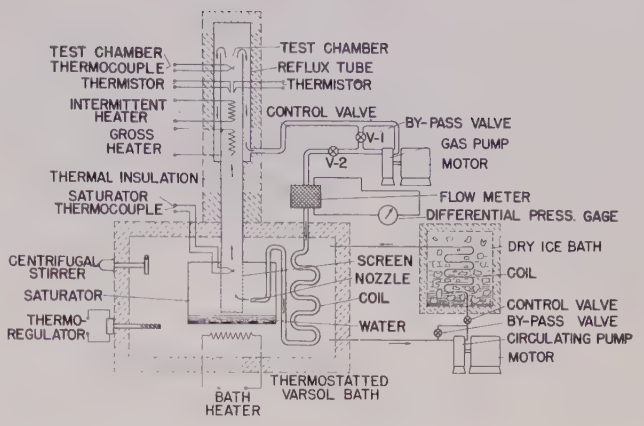

Fig. 8. Schematic drawing of NBS two-temperature humidity generator. Single recirculating system shown (2)

It is sometimes desirable to be able to make a rapid change of relative humidity from one discrete value to another. This can be achieved in this equipment by utilizing a number of identical but independent systems that are arranged in such a fashion that their test chambers may be interchanged easily and quickly. Thus if a different saturator temperature, t_s, is maintained in each of, say, four saturators, and if the same temperature, t_t, is maintained in each of four test chambers, then the relative humidity in each test chamber is different. By interchanging the saturators used with a test chamber, several different relative humidities at the same temperature can be provided in it in rapid succession.

The arrangement is shown schematically in Fig. 9 for two systems. The interchange of saturators is effected by a special pneumatic switch. It consists of two ground and lapped plates, with suitable ports, to which the test chambers are attached and through which air may pass. A turn of the top plate with respect to the bottom plate advances each test chamber to a new position and connects each chamber with a different saturator. Two such switches can be used instead of one, for greater convenience and versatility in changing saturators.

Divided Flow-Humidity Apparatus

The principle of divided flow is employed in this apparatus

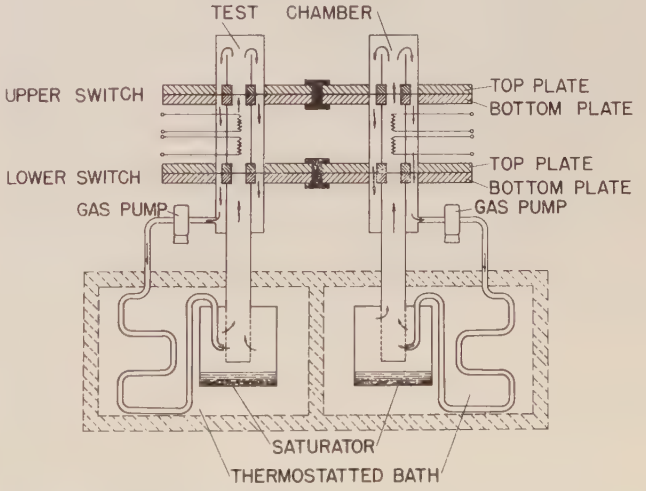

Fig. 9. Schematic diagram of pneumatic switches for interchanging test saturators of NBS two-temperature humidity generator. Only two of four recirculating systems shown (3)

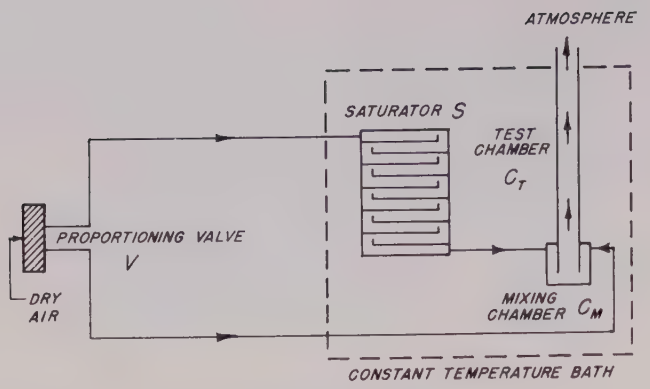

Fig. 10. Simplified schematic drawing of divided-flow humidity generator

to produce any desired humidity. Equipment based on this principle has been described by Walker and Ernst (*9*) for use at temperatures above freezing and by Glueckhauf (*40*) and Wexler (*41*) for use at temperatures below 0°C. A stream of dry air is divided accurately, usually by means of a proportioning valve, into two parts. One part is saturated with respect to water or ice; the other part is maintained dry. The two parts are then recombined in a test chamber and then exhausted into the room. The relative humidity is given by the ratio of the division.

Figure 10 is a simplified schematic diagram illustrating the principle of operation. By means of a proportioning valve, V, a flow of dry air is divided into two parts in a known ratio. One part is passed through a saturator, S, until it is completely saturated. The saturator shown in Fig. 10 is designed solely for ice. It consists of a series of trays into which water can be poured and then frozen. Other types of saturators can be used equally well; the design is not limited to ice saturators. The air after emerging from the saturator is then mixed in a mixing chamber, C_M, with the other stream that has been maintained dry, and then allowed to exhaust through a test chamber, C_T, into the atmosphere. The saturator, mixing chamber, and test chamber are kept immersed in a constant temperature bath.

By direct measurement, the total pressure, P_s, in the saturator and the total pressure, P_c, in the test chamber are known. The fraction, X, of air flow that is directed through the saturator is given by the setting of the proportioning valve. Since everything is at a known constant temperature, the pressure e_s of the saturated water vapor within the saturator, is also known (by recourse to standard tables of vapor pressure). The relative humidity in the test chamber is determined by these known parameters.

Consider a unit mass of air entering the proportioning valve and dividing into two parts; one part passes through the saturator and is saturated with water vapor while the other by-passes the saturator and remains dry. The portion, X, of air emerging from the saturator will contain Xr_s mass of water vapor, where r_s is the saturation mixing ratio, that is, mass of saturated water vapor per unit mass of dry air at the saturator temperature. After the two streams recombine, the air will contain r mass of water vapor per unit mass of dry air. The total mass of water vapor of the two separate streams is equal to the mass of water vapor of the recombined stream, i.e.,

$$Xr_s = r$$

or

$$X = \frac{r}{r_s} \tag{7}$$

The relative humidity in the test chamber is defined by

$$RH = \frac{e}{e_s} \times 100 \tag{8}$$

where e is the partial pressure of the water vapor in the test chamber. From Dalton's law of partial pressures, and assuming the perfect gas laws to apply, it follows that the mixing ratio of the air-water vapor mixture in the test chamber is

$$r = \frac{M_w}{M_a} \frac{e}{P_c - e} \tag{9a}$$

and that the saturation mixing ratio in the saturator is

$$r_s = \frac{M_w}{M_a} \frac{e_s}{P_s - e_s} \tag{9b}$$

where

M_a = molecular weight of air
M_w = molecular weight of water

Therefore

$$\frac{r}{r_s} = \frac{e}{e_s} \frac{(P_s - e_s)}{(P_c - e)} \tag{10}$$

By substituting equations (7) and (8) into equation (10), the relative humidity is obtained in terms of known quantities

$$RH = \frac{XP_c}{P_s - (1 - X)e_s} \times 100 \tag{11}$$

If the pressure drop from the saturator to the test chamber is made sufficiently small, then P_s may be considered equal to P_c. Furthermore, at low temperature, say below 0°C., e_s is negligible compared to P_s. Equation (11) therefore reduces to

$$RH = 100X \tag{12}$$

At higher temperatures, where the saturation pressure of water is no longer negligible, the relative humidity in the test chamber should be computed by equation (11).

Only under the stated conditions of small pressure drops and low temperatures is the relative humidity given by the proportioning ratio, X. On the other hand, the proportioning ratio X is a precise value of the per cent mixing ratio and so is a direct measure of the absolute humidity produced by the divided-flow apparatus.

A divided-flow apparatus designed specifically for use at temperatures below freezing is shown schematically in Fig. 11. It comprises the following functional units: (1) the drying system, (2) the proportioning system, (3) the humidifying system, (4) the mixing chamber, (5) the test chamber, (6) the cooling system, and (7) the thermostatting system for temperature control.

Air from a high pressure source is dried by freezing in a dry ice and Stoddard's solvent bath. The dry air is then brought to room temperature, its pressure reduced and controlled by a regulator, and passed through the proportioning system.

One type of proportioning system which is used consists of a valve which divides the air in a definite ratio by means of orifices. In one design of valve six orifices of equal cross-sectional area are so arranged that by a turn of the knob of the valve, the incoming air can by divided to produce any of seven ratios: 0, 1/6, 1/3, 1/2, 2/3, 5/6, and 1. These ratios are the fractions of air entering the valve that emerge through one of the exit channels. Since this exit channel is made to communicate with the saturating system, these ratios may be used as the values for X in equations (7), (9), (11), and (12). To assure that the air will divide in accordance with one of these given fixed ratios, the pressures downstream of the proportioning valve must be equalized. This is achieved by use of two variable resistances (pressure equalization valves) and a differential mercury manometer.

The two air streams, on leaving the proportioning system, flow through the humidifying system in parallel channels, into the mixing chamber where they are combined and centrifugally

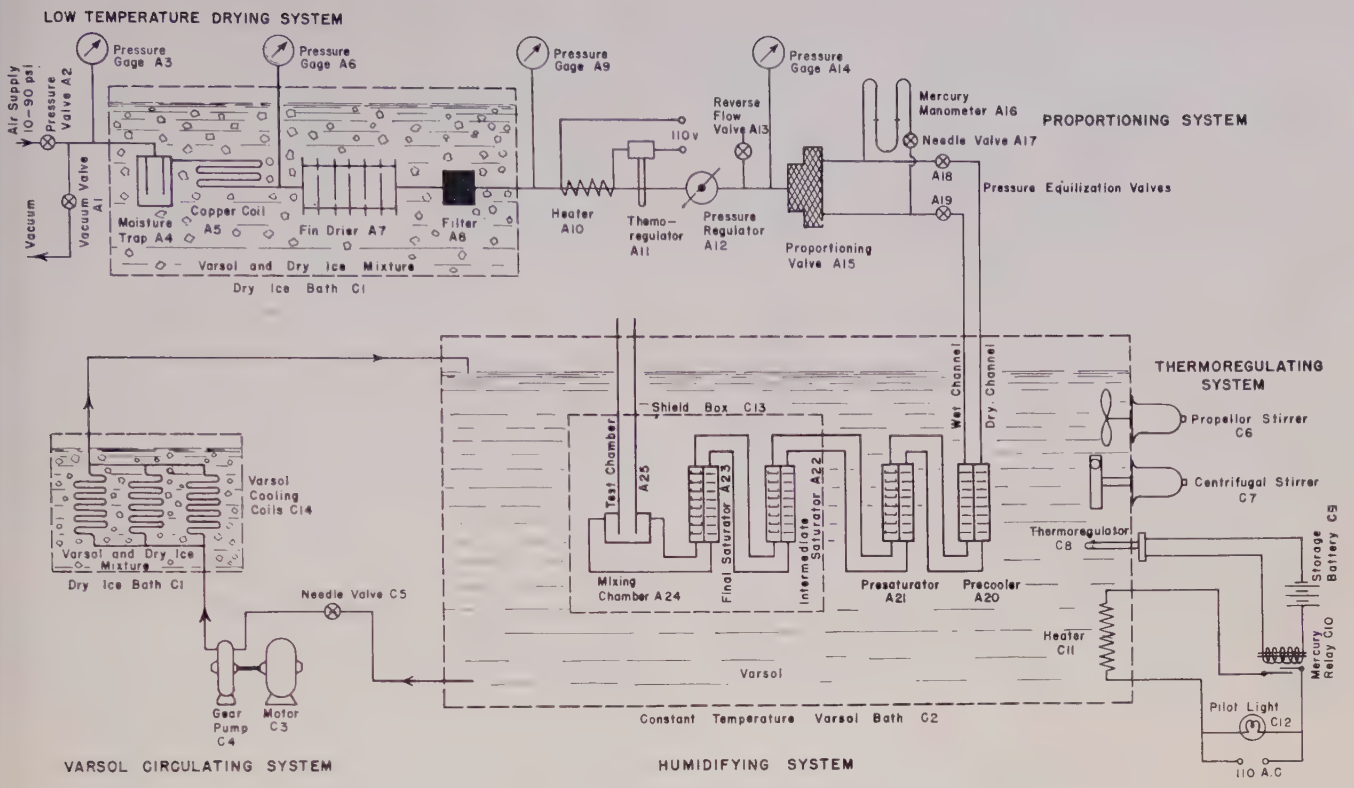

Fig. 11. Schematic drawing of NBS divided-flow humidity generator

mixed, then into the test chamber and are finally discharged into the atmosphere. The saturators, mixing chamber, and test chamber are immersed in a liquid bath that can be controlled at any desired temperature. For this particular apparatus, the temperature range is 0° to −40°C.

The divided-flow apparatus is a continuous-flow device in which the air speed through the test chamber can be adjusted and controlled. The rotation of the proportioning valve and the adjustment of the equalization valves are the only operations required for changing the relative humidity. The time involved is usually a matter of 1 or 2 sec. This permits any hygrometer under test in the test chamber to be subjected to a discrete change in relative humidity, a desirable advantage in the study of lag characteristics.

Apparatus Employing Combined Principles

Each of the generators so far described is based on a single principle of operation. It is, of course, possible to combine several of the principles for humidity generation into one apparatus. For example, the pressure humidity apparatus can be made more versatile by separately controlling the saturator and test chamber temperatures. The advantage of this is that low relative humidities can be reached without the need of extremely high saturator pressures. The relative humidity is then given by

$$RH = 100 \frac{P_s}{P_t} \times \frac{e_s\,(1 - K\,Pt + K'P_t)}{e_t\,(1 - K\,P_s + K'P_s)} \qquad (13)$$

where

P_t = test chamber pressure
P_s = saturator pressure
e_s = saturation vapor pressure at the saturator temperature
e_t = saturation vapor pressure at the test chamber temperature

In a similar fashion, the divided-flow apparatus can be designed so that the saturator system and test chamber are in separate temperature baths.

FIXED HUMIDITY POINTS

Very convenient methods exist for establishing atmospheres of known relative humidity which depend upon the equilibrium vapor pressure of water when a chemical is dissolved in it. The solution of a material in water lowers the vapor pressure of the water. The magnitude of the lowering depends on the concentration and temperature of the solution. These methods essentially provide fixed humidity points. They are ideally suited for controlling the relative humidity of a small space. Usually, little more is required than an enclosed space and an appropriate amount of chemical and water. Equilibrium conditions are more rapidly established, however, when air circulation or stirring, as by means of a fan or blower, is employed. When air circulation is used, the motor for driving the fan or blower is mounted externally to the test chamber to reduce any tendency for the chamber to warm up due to motor heat. The air circulation should be moderate, to reduce heating effects. In all these methods, the attainment of equilibrium depends on maintaining the chamber free of humidity sources or sinks. For this reason, the chamber should be fabricated from nonhygroscopic materials, preferably metal or glass. Materials which are highly hygroscopic, like wood, should not be used.

Saturated Salt Solutions

The saturated salt solution method is inexpensive, simple, and produces relative humidities that are roughly independent of temperature. The decided advantage of a saturated solution is that it can be made without measuring either the amount of salt or water. Since the concentration is fixed, for a given temperature, the ambient relative humidity is fixed. A saturated solution therefore provides an easily attained fixed humidity point. It is only useful at temperatures above the freezing point of the solution. A sealed chamber is required for which a large glass jar or bell jar is often suitable. The salt solution is made up as a slushy mixture in a glass or enameled tray or in the glass jar, if used, with the solution spreading over as large an area as practicable. Distilled water and chemically pure salts must be used. Stirring the solution may accelerate the attainment of equilibrium.

Table I. Saturated Salt Solutions Values of Relative Humidity Versus Temperature

Temperature, °C.	Relative humidity over saturated salt solution— $LiCl \cdot H_2O$, %	$MgCl_2 \cdot 6H_2O$, %	$Na_2Cr_2O_7 \cdot 2H_2O$, %	$Mg(NO_3)_2 \cdot 6H_2O$, %	NaCl, %	$(NH_4)_2SO_4$, %	KNO_3, %	K_2SO_4, %
0	14.7	35.0	60.6	60.6	74.9	83.7	97.6	99.1
5	14.0	34.6	59.3	59.2	75.1	82.6	96.6	98.4
10	13.3	34.2	57.9	57.8	75.2	81.7	95.5	97.9
15	12.8	33.9	56.6	56.3	75.3	81.1	94.4	97.5
20	12.4	33.6	55.2	54.9	75.5	80.6	93.2	97.2
25	12.0	33.2	53.8	53.4	75.8	80.3	92.0	96.9
30	11.8	32.8	52.5	52.0	75.6	80.0	90.7	96.6
35	11.7	32.5	51.2	50.6	75.5	79.8	89.3	96.4
40	11.6	32.1	49.8	49.2	75.4	79.6	87.9	96.2
45	11.5	31.8	48.5	47.7	75.1	79.3	86.5	96.0
50	11.4	31.4	47.1	46.3	74.7	79.1	85.0	95.8

Data for a number of saturated salt solutions have been compiled by various authors and in various handbooks (*42, 43, 44*). The salts listed in Table 1 have been particularly useful for hygrometer calibration work. The data in this table are based on dewpoint measurements (*45*). In general use, saturated salt solutions should not be expected to control the relative humidity to closer than about 1% R.H.

Water-Sulfuric Acid Solutions

Water-sulfuric acid mixtures produce atmospheres of relative humidity that depend on composition and temperature (*46–51*). The concentration of the mixture, at a given temperature, determines the ambient relative humidity. The temperature effect is small. The liquid may be exposed in a suitable tray in a sealed chamber to give the equilibrium vapor pressure of the mixture, or air may be otherwise brought into intimate contact with the liquid. Values of relative humidity, as a function of temperature and concentration, are given in Table II. Collins' data (*48*) are used for temperatures of 20 through 70°C. while Wilson's compilation (*46*) is used for 0°C.

To obtain a desired relative humidity, it is necessary to prepare a solution of proper concentration. In use, the concentration of the solution may change and some technique is needed to periodically check or measure the concentration. One scheme is to titrate a sample with a standard base of known concentration; another is to measure the density or specific gravity. Values of specific gravity, as a function of concentration, at 20°C. assuming the density of water at 4°C. as unity, are listed in Table II and are abridged from the "Handbook of Chemistry and Physics" (*44*). The concentration of the sulfuric acid solution can then be adjusted, if necessary, by the addition of a suitable amount of water or acid.

Table II. Relative Humidity Obtained from Water-Sulfuric Acid Solutions

% Sulfuric acid by weight	Specific gravity at 20°/4° °C.	Temperature, °C. 0	20	25	30	50	75
		Relative humidity, %					
10	1.0661	95.9	95.6	95.6	95.6	95.6	95.6
20	1.1394	87.8	88.0	88.0	88.0	88.2	88.5
25	1.1783	81.8	82.4	82.5	82.6	83.1	83.6
30	1.2185	73.8	75.0	75.2	75.4	76.2	77.2
35	1.2599	64.6	66.0	66.3	66.6	67.9	69.5
40	1.3028	54.2	56.1	56.5	56.9	58.5	60.5
45	1.3476	44.0	45.6	46.1	46.6	48.5	50.8
50	1.3951	33.6	35.2	35.7	36.2	38.3	41.0
55	1.4453	23.5	25.3	25.8	26.3	28.5	31.1
60	1.4983	14.6	16.1	16.6	17.1	19.0	21.4
65	1.5533	7.8	9.2	9.7	10.1	11.8	14.0
70	1.6105	...	3.4	3.7	4.1	5.4	7.2

Water-Glycerin Solutions

Water-glycerin mixtures will similarly produce atmospheres of known relative humidity (*52, 53*). The techniques employed with water-sulfuric acid mixtures work equally well with the water-glycerin mixtures. An important advantage of water-glycerin mixtures over water-sulfuric acid is that they are noncorrosive. The relative humidities obtained from various water-glycerin solutions are given in Table III. The values are based on the work of Grover and Nicol (*53*), who measured the vapor pressure at 20°C. and applied Duhring's rule to compute the vapor pressures at other temperatures. Table III also contains values of specific gravity, at 20°C. assuming the density of water at 4°C. as unity, abridged from the "Handbook of Chemistry and Physics" (*44*). A measurement of the specific gravity of a glycerin-water mixture provides a check on the concentration.

Table III. Relative Humidity Obtained from Water-Glycerin Mixtures

% Glycerin by weight	Specific gravity at 20° C./4°	Temperature, °C. 0	20	40	70
		Relative humidity, %			
20	1.0470	90.0	94.2	93.9	93.1
40	1.0995	82.2	86.5	86.6	86.2
60	1.1533	70.0	73.8	73.8	74.4
80	1.2079	49.6	51.7	50.9	50.5
90	1.2347	32.4	32.0	30.9	30.3

HUMIDITY CHAMBERS

In response to a sensing element, such as a mechanical hygrometer, electrical hygrometer, or psychrometer, the humidity of a closed space may be raised by water, spray or steam injection, by exposure to a water surface or wet wicks, or by the introduction of saturated or high humidity air, or the humidity may be lowered by chemical absorption or the introduction of dry air. Either manual or automatic controls may be used to achieve the desired humidity. The basic feature about humidity chambers of this kind is that they require or depend upon auxiliary humidity measuring devices for an indication of the moisture content of the air. There are many chambers of this sort described in the literature (*54–64*). Most of them are meant to be used at room temperature, or, perhaps, elevated temperatures, for testing materials and electrical instruments for the deleterious effects

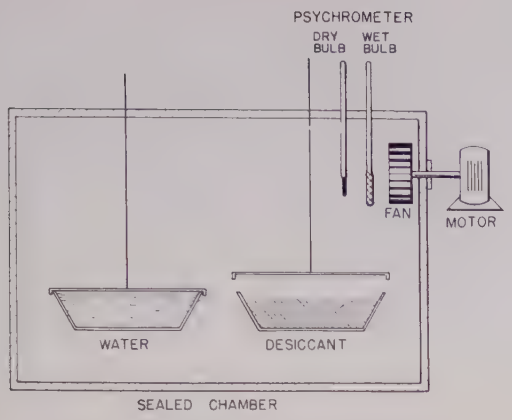

Fig. 12. Simple humidity chamber

of high humidity. Some chambers have been designed for vapor absorption or permeability studies.

Figure 12 is a sketch of a humidity chamber. Two trays, each with a tight cover that can be raised and lowered by external manipulation, are placed in the chamber. One tray contains a chemical absorbent, such as sulfuric acid, silica-gel, or Drierite, while the other contains distilled water, preferably with exposed cotton or linen wicks. The cover of the appropriate tray is raised until a hygrometer indicates that the desired relative humidity has been attained. The cover is then dropped and since the chamber is sealed, the humidity remains constant. The chamber may be made automatic by using the output of a sensing element, through an appropriate circuit (*62, 63*), to raise or lower the required cover.

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Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

Moderator Obenshain: I think we certainly ought to compliment Mr. Wexler on this excellent presentation and particularly on the fine quality of his slides which he had for us there. They were really remarkable in detail and could be seen at a glance.

Piero Bersano (Cartiere Burgo, Torino, Italy) (written comment): Mr. Wexler's work (is) very accurate and deep. The essay is really of outstanding value and it deals with the subject from the various scientific and practical angles with ample physical and mathematical explanations.

It is difficult not to agree with an author so documented and so deeply familiar with the subject.

Mr. Wink: We have received a number of similar letters from technical men here and abroad. All were highly complimentary of Mr. Wexler's work and expressed the importance of work in this area. A question was submitted with one of the letters but, before I turn to this question, I should like to ask Mr. Wexler on what basis he calculated the accuracy values that were given.

Mr. Wexler: The one part in a thousand that I mentioned is actually of the error in the absolute value of the moisture content that is being measured. It isn't relative humidity we are measuring. One can convert absolute humidity to relative humidity if one knows, in addition, the temperature of the test gas or atmosphere.

Mr. Wink: With regard to the submitted question, reference was made to your preprint as follows: "It was indicated in section 2.2 that the Bureau is now investigating

scientific instruments such as the dew point and microwave hygrometers for possible use as a secondary standard. Has the work progressed far enough for a preliminary opinion as to suitability?"

Mr. Wexler: Let me backtrack a little bit in order to answer the question. One of the reasons for building this gravimetric hygrometer is that the National Bureau of Standards intends to initiate a service for the scientific and industrial community. We intend to calibrate suitable instruments which can then serve as secondary standards or working standards in other laboratories. The secondary standards are the ones that are referred to in the question and we have as yet done little in the establishment of necessary criteria for the secondary standards. These instruments have to be of the caliber such that they can be used as laboratory or plant standards for comparison with working instruments and test instruments.

Our preliminary thinking has been that such instruments as the microwave hydrometers and the dewpoint indicator and perhaps one or two other devices might serve as secondary standards.

I phrase it this way because what we intend to do is investigate these various instruments to see whether they could serve as secondary standards. So far most of our work has been done with the microwave hygrometer and with the dewpoint hygrometer. The former is under development at the present time. In the past we have worked with manually and visually observed dewpoint hygrometers as well as with automatic photoelectric dewpoint hygrometers. Many of these automatic dewpoint hygrometers were commercial instruments but some were developed solely for scientific research purposes. However, all the automatic types fall far short of the accuracy achieved with the manually operated and visually observed dewpoint devices. However, the latter are very difficult to use and very often require two people for operation and, for that reason, they may not be practical for many applications.

Member: On this microwave hygrometer you mentioned, what is the size probe? Do you have to lighten the chamber that you have constructed for a primary standard?

Mr. Wexler: The microwave hygrometer would not be inserted inside a chamber when it is intercompared with the gravimetric hygrometer. Our intent is to generate a source of constant relative humidity, then to sample this source of constant relative humidity simultaneously with the gravimetric hygrometer and with the microwave hygrometer and in that fashion to get an intercomparison between the two. This will give us the calibration.

Dr. Clark: I had the privilege of receiving a copy of this paper a few days ago and on looking over it, it would appear to have no reference to some elegant work done by Wink as published by *Tappi* in 1950 which rather jolted me because in giving their figures for the relative humidity of the various salt solutions they were quite different to those in the International Critical Tables.

Mr. Wexler: The original source for those values is another paper in which the relative humidity temperature relationship of a number of salts were investigated. There were six or seven such salts and their relative humidity temperature characteristics were determined from 0 to 50°C. In that paper the results were compared with Mr. Wink's work, as well as with that of other investigators. The interesting thing about that comparison is that it shows that much of the data which are available in the literature show a considerable scatter. One of the reasons for that scatter is that some of the data had been obtained with such instruments as hair hygrometers. You can see that data so obtained may be quite unreliable.

Our intention had been to study, irrespective of whether this had been done before or not, some of the salt solutions we had been using in our own laboratory for establishing fixed points of relative humidity, and to do that over as wide a spread in temperature as we thought would be useful.

Mr. Newby (Crown Zellerbach Corp.): Just to bring this down to our own practical application, what kind of accuracy is it possible to obtain with a sling psychrometer such as is used in industry for measuring relative humidity?

Mr. Wexler: I would say that under optimum conditions you will be very fortunate if you achieve 2% and the accuracy can be much worse. I would say that on the average you are probably going to get an accuracy of 4 or 5%.

The use of a sling psychrometer is subject to a large number of sources of errors, most of which are not taken into account in routine use. Some of these sources are (1) radiation, (2) the accuracy of the thermometers, and (3) the effect of the presence of the observer on both the humidity and thermometer readings. All these factors effect the accuracy of the sling psychrometer.

If you do want to use a psychrometer then you probably should get an aspirated psychrometer.

Ted Thomas: Has there been done any evaluation work or comparative work on electronic humidity measuring elements that vary in resistance: If so, what are your findings?

Mr. Wexler: The Bureau not only has done work in that field but the original element, the so-called Dunmore element was developed at the Bureau. I am not quite sure I understand what you mean by what is my reaction to those elements. Do you mean as to what I think about their accuracies?

Mr. Thomas: Yes. You mentioned the photoelectric devices and how would it compare to those?

Mr. Wexler: I would say that the electric hygrometer has an accuracy of 1.5 to 2%.

Dr. Clark: Is that absolute?

Mr. Wexler: Relative humidity.

Dr. Clark: Fifty or fifty-one?

Mr. Wexler: If you are measuring relative humidity at 50%, it will be 50 ± 1.5 to 2% R.H. units.

Mr. Flint (Buckeye Cellulose Corp.): Where did you say the information on relative humidity over those various salt solutions were published? I believe you referred to them in this paper.

Mr. Wexler: It was published in the *Journal of Research.* If you wish the exact reference, it is "Relative Humidity Temperature Relationships of Some Saturated Salt Solutions" by A. Wexler and S. Hasegawa, *Journal of Research of the National Bureau of Standards,* Volume 53, page 19 (July, 1954).

Mr. Ackerman (Union Mills Paper Manufacturing Co.): I would like to know if you have any opinion on the accuracy of an electrical type of relative humidity indicator that would measure the electrical capacitance or change in capacitance.

Mr. Wexler: As far as I know, no such device is on the American market. There has been a device of this kind developed in England. I think it is on the English market. I have not seen or tested or had such a device in my laboratory.

Dr. Lashof: You know that the TAPPI standard is 50 ± 2%. If measured using existing commercial instruments, even the best, would you say that this is a realistic limitation?

Mr. Wexler: I would say it is probably the limit of what you can get with commercial instrumentation. Now, you might be able to use instruments which are more sensitive than that. Electric hygrometers, for example, have a great deal more sensitivity. They can be made with a sensitivity of a tenth of a per cent. However, in terms of accuracy, the value of relative humidity is not known better than 2% and, therefore, I would say that in setting up a chamber or a room, that you probably will not have a device which can control any better than 2% or, if it does, you will not have an instrument which can measure better than 2% to tell you what you have in that room.

DR. CLARK: What type of hygrometer would you recommend for measuring constant humidity in a room?

MR. WEXLER: Well, I don't know that I can make any recommendations. The reason I would rather not is that there are too many people who are in the commercial business and have an interest in one type of device as opposed to another.

DR. CLARK: Would you use an aspirating psychrometer?

MR. WEXLER: I would say that if you are going to use a psychrometer then it would be preferable to use an aspirating psychrometer with radiation shields and with careful attention to the wick that goes on the wet bulb.

The details as to how or what you should do in regard to aspirating psychrometers are described in National Bureau of Standards Circular 512. There you will find a list of the sources of error. You will find also an analysis of the errors that will result when either one or the other of the two thermometers is in error, and from this analysis you will then get a better conception of what is involved in trying to achieve a 2% accuracy with a psychrometer.

ERNEST E. WERLE (Darling and Co.): How accurate are the humidity percentages in the area of the saturated solutions, say in a closed chamber?

MR. WEXLER: The question is, how accurate is the saturated salt solution method. I have to answer that in this fashion. I think we have determined the values of relative humidity with respect to salt solutions to an accuracy of at least 1% or better. If you wish to use the salt solution, however, I don't know that you can achieve 1%. You may. You probably will achieve about 2% and only if you take certain precautions. Salt solutions will work and work well if you use them in a completely sealed chamber where there are no other sources or sinks of humidity. This implies that you are working in a chamber that is constructed of metal or glass or some of the very few plastics which do not absorb or give off water vapor. If you use a chamber which is made of wood or those forms of plastic which are hygroscopic, then I don't believe you will know what relative humidity you have. Furthermore, you must use a chamber which permits you to come to equilibrium in a reasonable length of time—one in which there is circulation of air, or otherwise you may get stratification of humidity. Further, if you use such a chamber, you must be assured that the chamber isn't located at a cold spot or hot spot, particularly when you are using a salt which gives a very high relative humidity. If you use such a salt, and if you are not careful, you will notice condensation on the interior surface of the chamber and the condensation will usually appear where the chamber is facing the cold point. Condensation is especially prevalent when the chamber is near or facing a window and it is winter.

Therefore, I find it difficult to estimate the accuracy of the relative humidity over a saturated solution. If the precautions just outlined are observed, then the accuracy may approach 1 to 2% R.H.

MR. WINK: I would like to add a comment. To achieve a constant relative humidity with the saturated salt solutions it is necessary that these be used in a constant temperature room. Furthermore, it is desirable to place the solutions in a thermally insulated box in order to minimize the effects of temperature fluctuations. A slow drift in temperature can be tolerated but rapid fluctuations in the ambient temperature can disturb the relative humidity above the solution. In a fluctuating temperature situation, the air and the solution within the vessel respond at different rates to temperature changes; this difference in rate of response leads to the variability in humidity.

MODERATOR OBENSHAIN: Thank you, Mr. Wexler and Mr. Wink, very much for this very interesting paper. I also wish to thank all of you people for the wonderful discussion that you have brought up before us.

It looks as though the market is wide open to anyone who can come up with a good relative humidity measuring device.

I believe all of us have a new conception of what accuracy and precision mean in the measurement of relative humidity and after listening to Mr. Wexler, I began to wonder if any humidity room means a thing—if we are trying to get this ±2% R.H. with instruments that cannot even measure it. Nevertheless, we all have humidity rooms, I am sure.

The next group of papers will deal with the construction, maintenance, and control of relative humidity rooms and chambers.

Dr. Hobbs is going to lead our discussion after the various papers have been presented and then we will have discussion from the floor as previously.

The first of our papers in the second group here comes from England. This paper is by J. A. Cairns of the Printing, Packaging and Allied Trades Research Associates, and will be presented by title only. The title of the paper is "The Design and Control of Test Rooms and Small Ovens."

The Design and Control of Test Rooms and Small Ovens

J. A. CAIRNS

The general design of humidity cabinets of both the saturated salt solution and the injection types is discussed, indicating the more important features of the mechanical construction, together with hints on the operation and maintenance of such cabinets. Some methods are given for measuring the conditions inside such enclosures, as well as the requirements for the close control of these conditions. The paper also deals with the design of small testing or storage rooms (of about 1000 cu. ft. capacity), these rooms representing the intermediate stage between a humidity cabinet and a conditioned laboratory. The problems encountered in rooms of conventional construction are outlined and a description is given of a novel building method which will apparently overcome some of these problems. Suitable plant for conditioning such a room is described. A brief description is given of the various methods of air conditioning a full sized laboratory and the suitability of certain control systems is discussed.

MOST of the physical properties of paper and paper products vary considerably with changes in their moisture content, and it is therefore extremely important that tests are carried out under closely controlled conditions of temperature and humidity.

The actual equilibrium moisture content of a sample will vary according to whether it has been conditioned from the wet or the dry side of the equilibrium point, so that often preconditioning of the sample is required.

Most of the testing can be done in a laboratory which is kept at the required conditions, but in some instances several different sets of conditions may be required. Where special atmospheres are required, they may be obtained by using either conditioning ovens or separate small rooms, depending upon the quantity and size of the samples.

While certain basic principles apply to all types of conditioning plant, each has its own peculiarities.

It is proposed to deal mainly with ovens and small rooms (of about 1000 cu. ft. capacity) in this paper after giving a general outline of the basic principles involved.

The air conditioning of a full-sized laboratory is usually a commercial undertaking, and the plant will vary so considerably according to the particular circumstances that only a brief description of the various types of plant is possible.

J. A. CAIRNS, The Printing, Packaging & Allied Trades Research Association PATRA House, Randalls Road, Leatherhead, Surrey, England.

GENERAL DESIGN PRINCIPLES

There is apparently not much similarity between an air-conditioned laboratory and a small conditioning oven, but there are certain basic principles applicable in both cases.

The requirement of such equipment is that it shall keep the air in the working space within certain specified limits of temperature and humidity. These limits are interdependent and certain variations in temperature can have a very marked effect upon the humidity variations.

There are three possible types of variation. The first, commonly called the "hunt," is primarily due to the action of the control elements. No matter how sensitive the controlling device is made, it still requires a small change in the conditions before it will respond. This means that there will be a slight difference between the "on" and "off" positions, and that the actual control level will oscillate about a mean value. These oscillations are usually of small amplitude and of short period, but this will depend upon the design of the controller, as well as its position. Several other factors such as air distribution will also influence the "hunt."

In addition, there can also be a gradual shift of the mean control level over a period of time, known as the "drift," and variations will exist between different points at the same instant of time. This last effect is usually called a "gradient."

The maximum possible variation that can occur over a period of time is the sum of these three effects, and the designer's problem is to reduce each effect to the smallest possible value.

The existence of a small temperature gradient can cause large variations in relative humidity. Figure 1 shows the magnitude of this effect at various nominal conditions. Thus if a standard condition of 23°C. and 50% R.H. is required the temperature gradient between any two points in the working space must not exceed 0.64°C.

If temperature gradients exist it usually indicates that the air distribution in the conditioned space is not good enough, and there is insufficient airflow at some points to overcome local heat gains or losses. When this is the case it is usually found that the level of the hunt is also high.

Good air distribution is the essential factor in obtaining control of conditions to close limits, as if the distribution is bad it will be impossible to obtain good control, no matter how good is the remainder of the plant.

To obtain good distribution the outlets must be so positioned and of such design that conditioned air reaches all parts of the working space in sufficient quantity. The factors affecting the design are so variable that each installation must be considered on its own merits and it is impossible to lay down hard and fast rules.

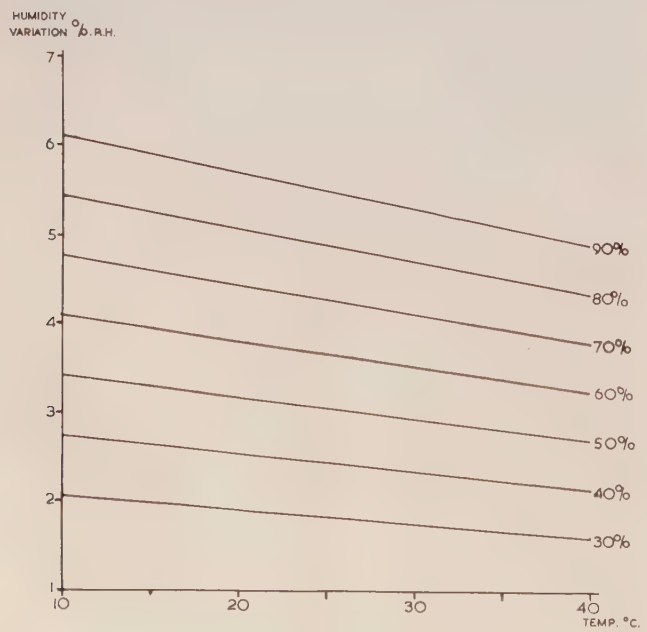

Fig. 1. Variation in R.H. per deg. C

To obtain control to the closest possible limits the recirculation rate should be as high as possible without causing draughts which interfere with the work in progress, and while it is difficult to quote a suitable figure complete recirculation should not take more than 10 min., and if possible should be about half this time.

The positioning of the control elements is a matter of extreme importance in determining the limits of control. They must be so placed that they receive a representative sample of conditioned air and any change in conditions affects them as quickly as possible. Any time lag in the response of the elements will increase the amplitude of the hunt. In general, provided that adequate circulation is provided, a position close to the return air inlet will give reasonable control, but in some cases the best position may have to be determined by a process of trial and error.

The accuracy of temperature control will depend to some extent upon the type of humidity controller used. If the humidity controller element responds to changes in the relative humidity then a slow drift of temperature will not adversely affect the humidity control. If, however, the humidity is controlled by a dew-point instrument or a wet bulb thermometer then a temperature drift will cause a variation in relative humidity. Controlling at 23°C., 50% R.H. a drift of 1°C. will give a 3% variation in relative humidity. There is therefore some advantage in using a controller which responds to changes in relative humidity in preference to one dependent upon the dew-point, although the former type will have a small, and usually negative, temperature coefficient.

It is advisable to provide filters for cleaning the conditioned air, as otherwise dust and paper fibers will become a nuisance. Not only will they be spread over the room and the test samples, but they will also collect on the heat exchanger, and in the humidifying equipment. This will impair the efficiency of the plant. The humidifying section is a source of dust which many people may tend to overlook. This part of the plant injects small droplets of water into the air. When these evaporate any dissolved solids in the water will be precipitated as a very fine powder, which may possess very abrasive properties, causing excessive wear of any instruments in use.

Some form of filter should be provided in the return air duct to remove these various contaminants from the atmosphere, and likewise in the fresh air inlet if the plant is used to provide ventilation.

Once an air conditioning system has been put into operation, it should be capable of remaining in service for long periods, and the second task of the designer is to produce equipment which is as reliable as possible.

There should be little difficulty as far as the mechanical construction is concerned, but it should be remembered that no equipment will remain indefinitely in good operational order without the carrying out of a regular maintenance schedule.

It is more difficult to ensure that the control equipment will continue operating correctly for long periods, but care in the design can eliminate most causes of trouble. Control devices can be classified into three types depending upon their method of operation. The first type is mechanically operated, the sensing elements controlling the operation of the plant directly, and can be ignored as their occurrence is rare, and the control obtained usually leaves much to be desired.

The two other types are either compressed air or electrically operated. It is usually found in practice with either type that the simpler the design of the controller the less likely it is to cause trouble.

Compressed air operated equipment can give years of

trouble-free operation provided that certain precautions are observed. The air supply to the equipment should be clean, care being taken to remove all oil, water, or solid matter from the supply. The pressure should also be kept as constant as possible, as most of these instruments work on small pressure differences controlled by a variable "bleed."

Suitable equipment for pressure regulation and air cleaning should be fitted in the supply line, as well as a reliable pressure gage. Regular maintenance should include draining off oil or water and cleaning of the filters at suitable intervals. Instructions for maintenance of the control instruments is usually provided by the manufacturer and should be adhered to rigidly.

The majority of control systems are electrically operated and here again reliability is a question of correct design. All components used should be run well within their rated capacities and the control box should be sufficiently ventilated to remove the heat dissipated by the various parts.

All relay contacts should also be run well within their rated loadings; especial care should be taken when switching inductive loads, as the back e.m.f. generated on the breaking of the contact will be much greater than the supply voltage. Where necessary spark suppressors should be fitted, either to prevent arcing causing contact wear, or to eliminate radio interference. It is preferable to mount all open relays with the actual contact surfaces vertical, to prevent dust settling on them and giving a high resistance or intermittent contact.

The control contacts should handle as low currents and voltages (preferably a.c.) as possible, to prevent arcing causing contact wear, with subsequent drifting of the control point. If suppressors are fitted across these contacts they must be so designed that, in a.c. circuits, the device does not pass enough current to operate the control relays.

It is impossible to be absolutely certain that a controller will not cause trouble, so wherever possible the system should be designed to "fail safe." This is of the utmost importance in a well insulated piece of equipment such as an oven or a small room. A failure of the thermostat control in the "on" position would soon cause the temperature to reach a dangerous level, and it is advisable to fit such equipment with a high level thermostat which will switch off the power supplies in such a case, and give an audible or visible warning of the failure.

If routine checks of the conditions are carried out at regular intervals it should be possible to get an indication of a possible failure of the sensing elements. If conditions remain steady then all should be well; but when the conditions appear to drift, and continual resetting of the instruments is necessary then the element itself is suspect. The routine check, coupled with visual examination of the control elements should give sufficient notice of an impending failure in time to rectify the trouble before actual breakdown occurs.

This section has covered most of the basic principles involved in the design and operation of conditioning equipment, and it now remains to see the practical application of the principles to particular types of equipment.

CONDITIONING OVENS

Conditioning ovens are best divided into two classes, depending upon the method used in obtaining humidity control, as the design requirements of the two types will be somewhat different. The use to which the oven can be put is dependent to some extent upon the system of control.

The two methods of humidifying are by the injection of moisture or by the use of a solution of appropriate vapor pressure. It is proposed to deal with the solution type of oven first, as the requirements are somewhat more stringent than the injection type.

The main advantage of this type is that it is only necessary to control the temperature accurately; the relative humidity control will then be automatic provided that certain other factors have been taken into consideration. The disadvantages are that the oven can only be used at certain relative humidities and that the rate of moisture transfer to or from the solution must be kept low if the humidity is to be kept within the required tolerance.

The advantage of the injection type of oven is that the moisture transfer can be as rapid as required, but the control may not be as good as a solution oven, because two factors must be controlled, the heat and the amount of moisture injected.

Solution Type of Oven

The relative humidity in this type of oven is controlled by the use of an aqueous solution, the vapor pressure of which will be constant at a constant temperature provided that the concentration of the solution remains unaltered.

The first requirement of an oven is that the airflow is sufficiently fast to give as rapid transfer of moisture as possible between the solution and the samples. The oven must be so designed that conditioned air reaches all parts of the working space, even when the oven has been loaded with samples. There are several methods of arranging the airflow, shown in Fig. 2, the first being to blow the air from one side to the other through perforations which are evenly distributed over the two sides. A second method is to extract the air at the rear of the working space at the top, where it passes between the rear wall of the oven and a false back, then over the solution tray at the bottom of the oven. It then describes a zig-zag path over each shelf in turn until it reaches the fan entry again.

This second system has been found to give excellent results in practice provided the air velocity is high enough, but has the slight disadvantage that an odd number of shelves must be used in the oven. Measurements of air velocities in a cabinet employing this type of circulation gave the following results:

Air speed over solution	16 ft. per sec.
Air speed over shelves	$2\frac{1}{2}$ ft. per sec.
Air speed at fan entry	40 ft. per sec.

A third method of air circulation sometimes used is to blow the air over the solution and out of a slit in the front of

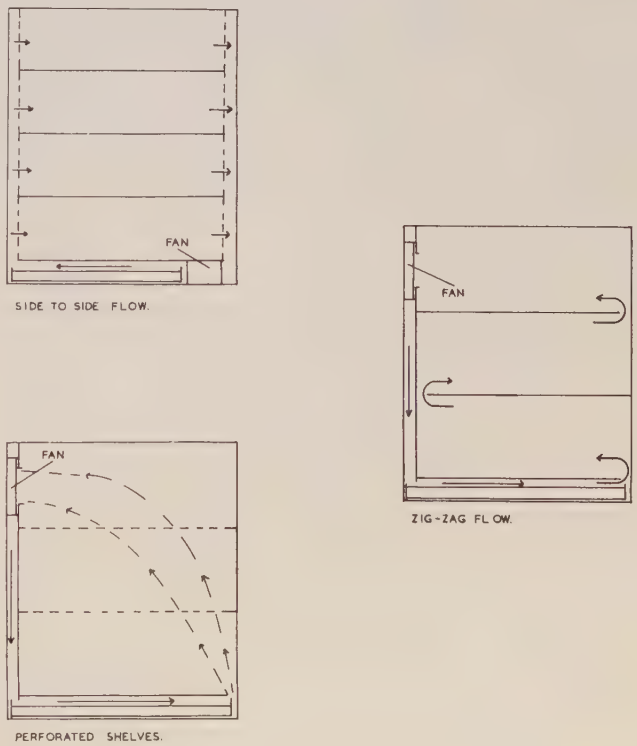

Fig. 2. Airflow in ovens

the working space. The fan intake is again situated at the top of the rear wall and perforated shelves are provided. In theory the air passes through these perforations, but with a loaded oven a large proportion of the perforations may be covered, and uneven flow with "dead spots" can easily occur. The first two systems will give a more even distribution.

It is advisable to keep the gap between the surface of the solution and the lowest shelf as small as possible as the separation directly affects the air velocity over the surface of the solution.

A factor affecting the mean level of the relative humidity is the rate of leakage of water vapor from the oven.

The magnitude of the effect is dependent upon the surface area of the salt solution and the air velocity over it as well as the cubic capacity of the oven. In an oven of about 5 cu. ft. capacity with a solution surface area of $2^1/_4$ sq. ft. (air velocity 16 ft. per sec.) a measured loss of 35 g. of moisture per day was found to lower the mean level of the relative humidity by 1%.

To reduce leakage it is necessary to have effective seals on the door and at all other points of entry into the working space. The doors should be sealed with a gasket of a suitable resilient material which should be affixed in such a manner that it can be easily replaced if necessary. Provision for adjustment of the door is necessary to ensure that the gasket makes an efficient seal, and some means of adjusting the clamping pressure is desirable. Both the door and the door frame must be made sufficiently rigid to withstand the required clamping pressure without undue distortion, and for ease of operation the clamps should be a quick release type.

The fan shaft must have a suitable seal; a felt washer impregnated with a silicone grease has been found to be suitable.

The temperature of the oven must be closely controlled and the oven must be lagged sufficiently to prevent condensation or the existence of temperature gradients across the working space. To prevent the formation of "cold spots" care must be taken in the positioning and the shape of any supports for the inner walls which may provide a heat path through the insulation; short supports with a large cross-sectional area must be avoided.

Ovens may be heated in several ways, but only two of these need to be considered. One possibility is to put electrical heaters in the air stream, and in this case the heaters should have a low thermal capacity as otherwise the time lag in their response to switching on or off will increase the magnitude of the hunt. The wattage of the heaters must be considered carefully, as too high a wattage will increase the hunt, while too small a wattage will give a long recovery time if conditions have been disturbed.

The second method is to use a water-jacketed oven and to heat the water with an immersion heater. This method will give a closer control of the temperature than the use of air heaters. At high temperatures and humidities the water jacket type is less likely to give rise to condensation as the walls of the oven are slightly warmer than in the air heater type, but under more moderate conditions there is little difference between the two types.

In either case careful setting of both the heaters and the thermostat is required if excessive hunting about the operating point is to be avoided. With the air heater type the air should pass over the thermostat before the heaters; with the air velocities required in these ovens the time lag in the response of the thermostat should be negligible. In the water-jacketed type the thermostat should be placed above and very near the heaters, but a baffle should be fitted to shield it from direct convection currents. If this is not done the "on-off" cycle will be very short and the oven will take a much longer time to reach the control point. Excessive wear of the thermostat contacts may also take place, and result in a gradual drift of the control point, or erratic control.

A humidity oven should be fitted with an observation window so that the contents can be observed without disturbing the conditions inside. Such a window should be double glazed and equipped with a low wattage heater to prevent the temperature of the glass falling to a point where misting would occur. This heater should be wired in parallel to the main heater so that there is no possibility of it affecting the conditions when operating near ambient temperature.

A double-glazed door is very suitable for the observation window as it provides an unobstructed view of the whole of the interior of the oven. To prevent heat losses an outer, well insulated, door should be provided.

The circulating fan should be as efficient as possible, to give the required air velocity with the minimum heating effect. A centrifugal fan is better than an axial-flow blower both for efficiency and ease of incorporation into the oven. The fan motor should be mounted externally, and wherever possible it should be an induction motor. A universal motor is fitted with carbon brushes and gives one more potential source of breakdown.

It will be found impossible to run at much less than 6–7°C. above the ambient temperature unless some form of cooling is provided. This is comparatively simple with a water jacketed oven, and merely entails the fitting of a cooling coil in the upper part of the water jacket.

With the air heater type some care must be taken in the design of cooling coils to avoid a continuous process of distillation of water from the solution to the coils.

The solutions used to obtain the required humidities may be either saturated aqueous solutions of a suitable salt or solutions of a known concentration of such compounds as sulfuric acid or glycerol. Both of these substances are miscible with water in all proportions and so solutions of any concentration can be obtained. Such solutions will change in concentration if they absorb or give off water vapor, and should only be used where the moisture transfer will be low. A careful watch must be kept to ensure that the concentration does remain reasonably constant.

It is more usual to use a saturated salt solution, for its concentration remains steady if the temperature is constant and so its vapor pressure will remain steady. Opinion is divided as to the best method of making up a saturated solution; some people insist that it is necessary to have an unbroken liquid surface, while others maintain it is better to add sufficient solid salt to produce a mobile slurry.

In theory the unbroken solution surface is the correct method, as the presence of solid salt exposed to the atmosphere may upset the equilibrium conditions, but in practice the difference in relative humidities obtained is not detectable. The use of a slurry has several advantages; it is much easier to handle, creepage of salt over the edge of the tray is reduced, and a slightly greater rate of evaporation is obtained, resulting in quicker recovery times.

Extreme care should be taken when using mixtures of salts to give particular relative humidities. The salts used in such a mixture must have a common ion, to prevent other salts being formed by double decomposition, when crystallization or solution of the products might affect the concentration. The salts should also crystallize in different forms to prevent the crystallization of a double salt, which may again affect the vapor pressure of the solution. It is also preferable that the solid salts should contain no water of crystallization, as one salt might affect the degree of hydration of the other.

Much information has been published on the relative humidities over saturated salt solutions, and in certain instances the quoted values vary widely. Where results do not agree closely, a check on the experimental method used in the determinations should enable a decision to be made as to the correct result.

Because a particular relative humidity is quoted as obtained with a solution, that is no guarantee that this humidity is being obtained. A check on the oven conditions should be carried out at regular intervals, and any variation from the correct value should be noted. This procedure gives an additional check on the leakage from the cabinet and if low values are obtained the sealing gaskets might need adjustment.

All ovens should be provided with means of inserting measuring instruments into the working space, without disturbing the equilibrium conditions in the oven, so that a check can be carried out when required.

Injection Type Ovens

The humidity in these ovens is maintained by the injection of water or steam into the working space. If required to run below ambient conditions, dehumidification or cooling can be carried out by means of a cooling coil.

In these ovens both temperature and humidity have to be controlled and in general the control will be to less fine limits than can be obtained with the solution type, but for certain purposes there is some advantage in using these ovens.

The rate of moisture transfer can be much higher than with a solution oven, while a second advantage is that the oven can be cycled between various conditions if required. The time to regain the original condition of humidity after any disturbance will be less than with the solution type.

The construction of the oven is not so critical as in the first type, as the effect of leakage will be much smaller, but the temperature control required in both types is similar.

In an injection oven there will be a variable heating load, due to the humidification process. Thus if steam injection is used extra heat will be supplied due to the difference in temperature, but water injection will require extra heat to replace the latent heat of evaporation. It may be necessary to insert tempering heaters or cooling coils in the air stream immediately following the humidifying device to counteract these effects to prevent excessive hunting of the temperature.

If steam injection is used the size of the boiler and its heater is important, as too much water or the wrong size of heater will give a time lag in its response and cause a hunt of the relative humidity. If water injection is used control will be by a solenoid valve and response will be immediate, but it is advisable to provide baffles in the airstream to remove any large droplets of water, thus preventing overhumidification or damage to the samples. In practice the solenoid valve will be more reliable in operation if it is a diaphragm type, as the needle valves have a tendency to stick open when dirty. The water line should of course be fitted with a suitable filter. As in the case of the solution type of oven an efficient air circulation is the prime consideration in the design of the equipment.

Control and Measurement of Oven Conditions

The temperature of the oven must be controlled to as fine limits as are possible, bearing in mind the large change in relative humidity that can be caused by small temperature variations. The control element should be as sensitive as possible, and the contact movement should be reduced to a minimum. Where possible "snap action" of the controller should be avoided to keep the operating differential to a minimum, and any time delay to prevent chattering of the relays should be incorporated in the control circuit. Voltages and currents at the controller contacts should be kept as small as possible to prevent contact wear which may cause a drift of the control level.

In situations where excessive vibration is experienced some snap action may be necessary, but it should be kept to a minimum otherwise the hunt may be increased.

The wattage and thermal capacity of the heater will affect the limits of control, too large a heater causing "overshoot" of the control point due to the residual heat of the element after it is switched off. But the size of heater will be a compromise between that suitable for accurate control, and the wattage required to give a short recovery time after disturbance of the conditions.

If due consideration is given to the points mentioned then it is possible to construct an oven in which the temperature control is better than $\pm 0.5°C$.

Humidity control in injection ovens may be by any suitable means, but with certain types of control elements drift of the dry bulb temperature will affect the control level of the relative humidity and the temperature controller must be as stable as possible.

Controllers which respond to changes in relative humidity usually suffer from hysteresis if the relative humidity fluctuates, and where possible should not be used where cyclic variation of the conditions is required.

The conditions inside the oven should be checked at regular intervals to ensure that the equipment is operating satisfactorily. One suitable method of measurement is to insert a wet and dry bulb psychrometer through a tubulure in the top of the oven. The position of the bulbs should be such that the air flow over them exceeds 3 m. per sec., and a position immediately in front of the fan entry has been found to be suitable. When not in use the tubulure should be closed with a stopper fitting the inside end, but capable of insertion and withdrawal from outside.

Other instruments such as a dew-point apparatus or an electrical type of hygrometer can be used, but these instruments either suffer from drift or hysteresis, or in the case of the dew-point apparatus, require a skilled operator. The wet and dry bulb hygrometer is capable of giving reasonably accurate results in the hands of a semiskilled operator.

SMALL ROOMS

Where it is not convenient to use an oven, such as when large quantities of samples must be conditioned it may be necessary to use a small conditioned room. There are few problems in the structural design of rooms to be run at moderate conditions, but some difficulties arise where extremely high humidities are required.

Structural Requirements

The structure of a room can be regarded as being composed of three main sections, an external wall to protect the insulation, a layer of thermal insulation of the required thickness, and an internal moisture barrier. According to the actual conditions required the second or third sections may not be needed. It is proposed to deal only with rooms running at high or low humidities, and the special case of rooms for obtaining cyclic variation of conditions.

The external walls may be of any suitable material, and are quite often the existing walls of the building. The insulation may be of any suitable type, except that compressed cork is essential for the insulation of the floor, as it is the most easily obtained insulator which will withstand heavy loads without undue compression. The thickness of the insulation will depend upon several factors, but in general an equivalent of 6 in. of cork will prevent condensation occurring when running at 100°F., 90% R.H. Such factors as the temperature difference between the inside and outside of the rooms, the relative humidity, and the air velocity over the internal surface will affect the actual thickness required.

When running at very high or low humidities some form of moisture barrier is required to prevent moisture transfer through the insulation. At low humidities moisture leakage into the room might put an excessive load on the drier, whereas moisture loss at high humidities may saturate the insulation, and impair its efficiency. Certain insulators such as cork may be attacked by molds when wet and a breakdown of the structure may follow.

One possible method of making a moisture barrier is to cover the internal surfaces with lead foil, except the floor which may be sealed by a layer of high melting point asphalt. A plastic sheet material could be used in place of the lead.

The door should have the same amount of insulation as the walls and should be provided with an efficient seal to prevent loss of moisture. When running at high temperatures and humidities condensation will most probably occur around the door, and a low wattage heater embedded in the door frame will provide local heating. If sealing is effected by means of a gasket and clamps both the door and the surrounding frame must be able to withstand the clamping pressure without distorting.

Condensation may also occur at any points where fittings, conduits, or other metal objects provide a low resistance heat path through the insulation, so that some local heating may be required at these points also.

Rooms constructed as described have been built from a number of dissimilar materials, each having a different coefficient of expansion. If the temperature of the room is varied, and this happens every time the door is opened, the different parts of the structure will change in length by different amounts. This will set up stresses in the structure and the moisture barrier will be cracked or will begin to peel off the walls. Any paint on the inside surface will also begin to peel, and if a metal foil barrier has been used, rapid corrosion will occur.

To keep the room in good operational condition constant maintenance is required and if a suitable alternative method of construction could be employed a great deal of this maintenance could be avoided.

The ideal method of building would be to construct the inner shell of the room from one material. This material would have to be unaffected by extremes of conditions, and impervious to moisture. It must also be strong enough to be self-supporting and also be able to carry the weight of the insulation.

The material must also be strong enough to withstand any strains set up by temperature variations, be easily repairable if damaged, and be easily worked into the required shapes.

One such material that possesses all these properties is resin bonded glass fiber laminate, and rooms have been constructed in this material. The finished room was in the form of a free standing box made by bolting flat panels together by means of flanges around their edges, all joints being sealed with a stopper paste of the same resin.

To avoid the difficulties of molding very thick structures for the door and door frame, the compressible gasket method of sealing was not used. The door was sealed by means of an inflatable rubber tube, similar to a cycle inner tube, let into a groove around the edge of the door. When this tube is inflated with compressed air at about 6 to 8 p.s.i. pressure a very effective seal results, and it is only necessary to use a light ball catch to hold the door.

Rooms constructed in this manner have been functioning for some time and appear to be giving satisfactory service. The main problem is that the result will permit mold growth on its surface, a trouble which does not occur with a lead-lined room, but it is possible that this can be overcome by the use of suitable inhibitors in the surface of the panels.

Plant Requirements

Provided that the plant is properly designed, control to very fine limits can be achieved in a small room of say 1000 cu. ft. capacity. If the staff only enter the room for short periods no ventilation need be provided and the room can be made a sealed self-contained unit. Under these conditions control to ±0.2°C. and ±0.75% R.H. has been obtained when running at 38°C., 90% R.H.

The most important requirement is again good circulation. The ducting should distribute air to all points in the room, and the fan should be of such a capacity that complete recirculation takes place in 3 to 4 min. This will ensure a quick response to changes in conditions.

The order in which the component parts of the plant are arranged is important and the suggested arrangement is:

1. Air filters.
2. Control elements.
3. Fan.
4. Refrigerator and drainage sump.
5. Heaters and high temperature cut-out.
6. Humidifying sprays.
7. Spray baffles and drainage sump.
8. Distribution duct.

Any components not required in a particular installation can be omitted, or additional apparatus may be required to suit particular purposes.

The control elements can be of any suitable type, an adjustable contact thermometer will give good control of the temperature, while a silk-skein or parchment strip humidistat is capable of good control of humidity up to 95% R.H. Commercially available humidistats may require some slight alterations to improve their performance, such as the removal of any snap-action, and the adjustment of contact clearances.

Where instruments are required to control two opposing actions, such as heating and cooling, which may be necessary when operating near the ambient conditions, it is better to use a controller with changeover contacts or two separate controllers. This will allow the system to be adjusted to give a small neutral gap at the control point, where neither circuit is switched on.

The use of a single contact control operating a changeover relay is not to be recommended, as this will cause hunting about the control point.

Two types of fan are in common use, the axial-flow blower and the centrifugal fan. The axial-flow blower is easier to fit into a length of straight ducting, but the centrifugal fan is more efficient for a given capacity, and operates better against a back pressure. It is also less noisy in operation. In a self-contained unit the efficiency of the fan should be as high as possible, as all its power consumption must finally appear as heat. A typical axial-flow blower delivering 300 c.f.m. was rated at 80 watts and provided about 275 B.t.u. per hr. If a room is to be run near the ambient temperature, some form of cooling will be required.

Heaters can be of any suitable type but they should have a low thermal capacity to prevent time lag in their response increasing the hunt. For the same reason the wattage of the controlling heater should be as low as possible, and where sudden large changes in temperature are required, an additional boost heater of higher wattage should be provided. This heater can be controlled by a separate thermostat adjusted to cut-out one or two degrees below the control point. Such a system will give both rapid recovery and close control.

Humidification can be carried out either by an atomizer operated by compressed air, or by a direct mains water spray. The former will give quicker evaporation, but the latter is simpler to install, but it must be followed by a set of baffles to remove large droplets from the air stream.

Where a room is to produce a cyclic variation of conditions certain precautions may have to be taken, as heavy condensation may occur. In this case the ceiling should slope to allow it to drain, and the floor should fall away to a drain in one corner. Any equipment mounted on the walls should be protected from condensation by watersheds made from small strips of some material fixed to the wall over the equipment and sloped to allow drainage.

It is difficult to cool the room without reducing the relative humidity, as either the use of a heat exchanger in the duct, or washing the walls with chilled water will cause dehumidification. A better system is to use the humidifying spray as a means of cooling. A slower rate of cooling will be ob-

tained, and dehumidification will not occur. It may be difficult to keep good control of humidity during this part of the cycle.

It should be noted that condensation will only occur during the heating period of the cycle, when moist warm air is coming in contact with cold surfaces.

In all cases where electrical apparatus is installed in conditions of high humidities, it is essential in the interests of safety, that all wiring shall conform rigidly to the appropriate regulations. Waterproof fittings should be used throughout, and regular tests and inspection of the installation must be carried out. In particular great care should be taken in the earthing of all equipment.

CONDITIONED LABORATORIES

Although this subject is a little outside the scope of this article, some mention should be made of commercial plants to give a complete picture of air conditioning for testing purposes. The design of a full-scale plant is very complex, and generally requires the services of a qualified air conditioning engineer. This may be an appropriate place to point out that there is a vast difference between air conditioning for comfort and conditioning to the close limits required in a testing laboratory.

It is not proposed to deal with the design problem as this is covered thoroughly in a number of textbooks, such as the "Heating, Ventilating, and Air-conditioning Guide" published by the American Society of Heating and Air-conditioning Engineers, which gives a very comprehensive survey of the subject.

The following points must be considered before deciding upon the installation of any plant:

1. The required laboratory conditions and the limits of control required. Probably the most important point is the temperature variation allowable to keep the relative humidity within the required tolerance.

2. The range of external conditions under which the plant will maintain control. If the plant is required to function at all times, then the worst possible external conditions must be considered, but if a few days off control in the year can be tolerated, the cost of the installation will be reduced.

3. The space required to be conditioned, bearing in mind any future extensions.

4. The layout of the ductwork, which will determine the air distribution obtained. This must be considered together with the design of the outlets to enable sufficient circulation and ventilation, while avoiding draughts.

5. The method of heating, in particular the use of existing background heating. It is preferable that all the heat required is supplied by the plant, as with a high level of background heat the outflowing air will appear to be very cold.

6. The permissible noise level. This figure is difficult to determine as it is dependent upon the pitch of the noise. There are two types of noise, mechanical vibration transmitted by the ductwork, and air noise from the fan transmitted through the air stream. The former can be considerably reduced by making the connection between the plant and the duct by means of a flexible canvas sleeve, which will not permit the transfer of the vibration. Noise due to the fan is of higher pitch and is much more objectionable. An axial-flow blower will give more noise than a centrifugal fan of the same capacity, due to the much higher speed of the blade tips. It is better to use the centrifugal fan where possible to remove the source of the noise, as sound insulation can be a very costly item.

It is best in a testing laboratory to use a ducted system as it is then much easier to ensure good air distribution, and the installation of ductless unit conditioners should be carefully considered to see if they are capable of giving the required control. The usual fault with unit conditioners is that the fan is much too small to give the required circulation. The use of unit heaters, unit humidifiers, etc., scattered about the room will very rarely provide adequate control.

SUMMARY

The basis of close control is in all cases good air distribution, for without this it is impossible to keep all points at the same conditions. Provided that this is realized and that the controllers are sensitive enough and have quick response to changes in conditions, it is possible to control to very close limits.

Reliability of control is partly a matter of suitable design, but is finally dependent upon the adherence to a rigid maintenance schedule, to ensure that any trouble is rectified before an actual breakdown occurs.

Presented at the 11th Testing Conference of the Technical Associaton of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

I will now call upon Dr. Hobbs for a discussion of this paper.

Dr. Hobbs: I was very hesitant to occupy this position this afternoon because of my ignorance of the subject. However, after the papers we have heard today, I think you will all agree we are distinguishable only by our degree of ignorance.

I think that copies of Mr. Cairns' paper were made available to you at the registration desk. Probably most of us have had an opportunity to look at it already. I should only like to read some comments which have already been submitted on this.

These comments have been submitted by M. H. VanderVelde (J. O. Ross Engineering Div., Midland-Ross Corp.) and read as follows:

"The following comments are mainly applicable to small test rooms, as the writer's experience has been mainly with small laboratory test rooms, rather than test ovens.

"Comments in Mr. Cairns' article on the variation of relative humidity with dry bulb at a constant dewpoint are particularly pertinent. Most moisture measuring instruments have a relatively slow response and so from a practical standpoint, accurate temperature control as described in the article, is a necessity if close control of relative humidity is to be maintained.

"Test rooms for determining dimensional variation with variation in relative humidity present a problem where extremely accurate control is required if reproducible results are to be obtained. Dimensional change of paper with relative humidity is rapid and so will follow hunting of the humidity controller. Since actual conditions vary more than indicated by the controller under hunting conditions, indicated control should be within very narrow limits if accurately reproducible test results are to be maintained. This may be true of other paper characteristics also, but is most apparent in the dimension test.

"Since accuracte temperature control is a practical requirement for close relative humidity control, control systems other than the on-off, as described in the article, should be considered.

"An anticipatory control thermostat is very simple and can do much to eliminate hunting with on-off control.

"Modulating control thermostats and final control elements can do much to eliminate the hunting experienced with on-off control.

"Modulating control can in effect be obtained by percentage timers, controlling the percent of time-on on relatively short cycles. This arrangement does give the electrical contactor quite a work-out; however, since electric heating loads are by nature noninductive, the contactors job is relatively easy.

"Installations of this type with moderately oversized contactors have given years of trouble-free performance.

"Electric heat can be truly modulated by variable voltage

control, which can be effected quite easily with a saturated core type transformer. In this case, an alternating current output can be controlled by a small d.c. current easily developed by a control instrument.

"As outlined in the article, control of the enclosure wall temperatures is very important, if high humidities are to be maintained. For small ovens, water jacketing, as described in the article, will be undoubtedly a very effective means for the control of wall temperature. On larger rooms, double wall construction with a separate temperature controlled air supply between the walls should be considered in place of the extremely thick insulation which would otherwise be required. Depending on conditions, the double wall construction, with a system for holding the air temperature in a space above the dewpoint to be maintained in the enclosure can well be a more practical solution. Where extremely high relative humidities, close to 100% are desired, this arrangement is definitely more versatile than the thick wall insulation type.

"In addition to the methods of humidity control described, water injection and steam spray, the use of an air washer should be considered. Extremely accurate humidity control with simple instruments can be obtained with an air washer. The advantage of being able to add or withdraw moisture with such a system is a definite advantage."

Mr. Cairns (written reply): The author would like to thank Mr. Vander Velde of J. P. Ross Engineering for his comments and has the following remarks to make:

While both anticipatory control thermostats and modulating thermostats can be simple in design and operation, for a number of purposes the plain on-off control is perfectly satisfactory, provided that the recirculation rate is high enough.

In the writer's experience of rooms of 1000 cu. ft. capacity with a recirculation rate of 300 c.f.m. the on-off control will hold both temperature and humidity well within the required tolerances (±1°C., ±2% R.H.). In one room running at 38°C., 90% R.H., an on-off control was found to hold conditions to ±0.2°C. and ±0.75% R.H.

Where the air-flow is not so great, small changes in the out-flowing air will not have an immediate effect upon the controllers, and in such a case a modulated or proportionating control will give better regulation.

It should, however, be borne in mind that with such controllers there is a tendency for a change in thermal loading to vary the actual control point. An increased load will lower the control point and vice versa; so that where a variable thermal load is expected a combined integral and proportionating control is preferable. Such a control is commercially available in this country, and without doubt can also be obtained in the United States.

The author has had no practical experience of the use of a saturated core transformer, but this is obviously an excellent method of controlling proportional electrical heating.

Proportionating control devices, operated by compressed air or electricity, can of course be used to control heating, cooling, or humidifying. Where electrical systems are used, it is preferable to employ sensing elements such as resistance thermometers and dew cells, which do not have any moving parts.

In practice it is difficult to set the correct contact pressure on electro-mechanical devices, such as potentiometers with mechanical adjustment of the wiper arm. The controller in operation is either sluggish in response or gives an intermittent contact.

An air washer should be suitable for accurate humidity control both above and below the ambient humidity. It is admirably suited to proportionating control by means of a mixing valve controlling the proportions of chilled and recirculated water to the spray units.

Mr. Vander Velde's remarks on the dangers of condensation at high humidities are extremely pertinent, and his suggestion that a double wall construction employing heated air between the two skins is a useful one, but extreme care must be exercised in the design and construction of the floor, and also in the fitting of any supports bridging the gap between the inner and outer skins. At these high humidities and using such a construction the heating effect of the circulation fan must be taken into account. With humidities very near saturation, and a high rate of air circulation, it would still be possible for the walls to be at a temperature below the dew point.

Dr. Hobbs: Now, I am not in a position to add any comments of my own and I don't quite know what disposition we would make of questions from the floor. Perhaps some others will be in a position to answer the questions that might be asked. Or, if there are any comments, we will certainly welcome them.

Moderator Obenshain: Maybe after the group of papers has been presented, Dr. Hobbs, we can have questions from the floor in general. I did not realize that the paper had been available to very many people and if anyone who has studied this paper would like to ask something or answer any question, we are ready for it. Is there anyone?

Mr. Wexler: I would like to call your attention to Fig. 1 of this paper which I think is a very excellent presentation of one of the problems that is involved in humidity control. It shows the variation in relative humidity at various relative humidities for a given variation in temperature. If you are concerned, say, with controlling at 50% R.H. and at room temperature, you will find that a 1° variation in temperature in degrees Centrigrade will produce something on the order of 3.25% variation in relative humidity. Therefore, you will find that if you want better control in connection with relative humidity, you must get better control with temperature.

Mr. Cairns (written reply): The author would like to thank Mr. Wexler for drawing attention to the change of relative humidity with temperature variation. This is one of the major problems in accurate humidity control, and it is a point that cannot be overstressed.

Moderator Obenshain: Are there any other comments regarding this paper? If not, then we shall proceed with our next paper of the afternoon.

This paper will be presented by L. L. Clapp of the St. Regis Paper Co., Pensacola, Fla., and is entitled, "A Room for Mill Control Testing of Paper."

Mr. Clapp received his Bachelor of Science degree in Chemistry from the College of Charleston, S. C. Mr. Clapp is not new to our rostrum, having presented a paper here last year entitled, "A Device for Measuring the Curling Tendency of Paper."

A Room for Mill Control Testing of Paper

LAWRENCE L. CLAPP

A room located near paper machines and designed to accommodate considerable traffic while maintaining atmospheric conditions moderately close to standard has been in successful operation for six years. A system for rapidly conditioning paper samples for testing has been used therein for three years. A description is presented of the room, the air conditioning equipment, the control instrumentation, and the rapid conditioning unit. The influence of the practice of rapid conditioning on the sampling, testing, and reporting sequence is discussed.

The construction of a new machine which would more than double the production of one of our paper mills rendered obsolete the existing constant humidity room. In planning a new room it was decided that space should be provided not only for the additional technicians and equipment needed but

Lawrence L. Clapp, Process and Equipment Design Engineer, Technical Div., St. Regis Paper Co., Pensacola, Fla.

also for equipment which might be needed later as changes in testing procedures were made. It was also decided that conditioning equipment should be of sufficient capacity to maintain stable conditions in spite of considerable in-and-out traffic. To achieve the latter, a risk was taken of overdesigning the equipment but it was felt that the expected results would justify the added expense. As predicted, additional testing equipment was installed and the conditioning equipment turned out to be not much more than sufficient to handle extreme traffic and external environmental loads.

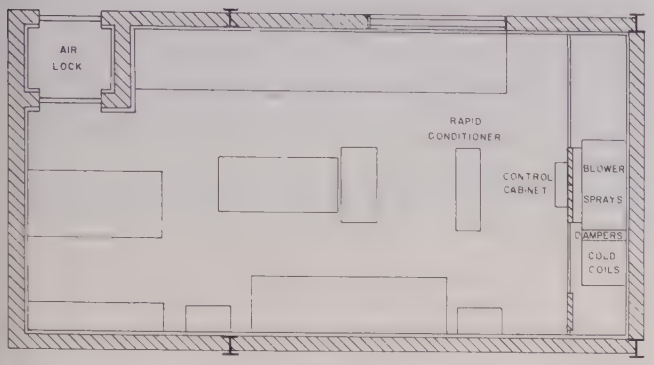

Fig. 1. Floor plan

CONSTRUCTION OF ROOM

The room was built of cinder block with a reinforced concrete roof. The interior of the shell was coated with asphalt emulsion for a vapor barrier, furring strips were installed on the side walls and steel framing on the ceiling to which metal lath was attached and the entire interior finished with plaster. Dimensions inside the plaster were 13 ft. and 6 in. by 26 ft. and 6 in. with a 10 ft. ceiling height. A 3 by 4 ft. air-lock with two doors occupies a corner and at the end opposite a baffle wall of wood framing and gypsum board encloses the air conditioning equipment leaving an operating area of 13 ft. and 6 in. by 24 ft. A floor plan is given in Fig. 1.

CONDITIONING EQUIPMENT

The design of the air conditioning system is an expansion of a design suggested about 14 years ago by Clark (*1*), two small rooms of this type having been operated several years successfully. The method employed in this system is that of circulating the air in the room fairly rapidly and then adding to the stream cold, dry air in small amounts, heating the entire stream, or adding to it water vapor as required.

The earlier systems used a single cold coil, heater bank, and spray nozzle each operated by high-neutral-low controls. It was felt that some type of proportional control would be advantageous as the response of units of the size needed for a large room might be too rapid and therefore cause wide fluctuations in conditions when only slight corrections would be required. Consequently, three each of the above elements were provided. An isometric view of the room and equipment is shown in Fig. 2. The three cold coils, each with a propeller fan for forcing air through it and a damper for isolation from the air stream, are stacked about 2 ft. from one end of the baffled space with the dampers connected to a central plenum chamber. A frame 20 by 60 in. holding air filters is inserted in the baffle to admit air to the coils.

Across the lower part of the plenum chamber are arranged three sets of three pneumatic atomizing nozzles and near the top is a 2 hp. blower discharging the air through a three-circuit blast coil heater and then through a central duct below the ceiling for distribution to the room through two round anemostats. The three 2-ton condensing units for the cold coils are mounted on the roof as are the power switchgear and a portion of the control system.

CONTROL SYSTEM

The humidistat and thermostat together with a circular chart temperature and humidity recorder are located in a cabinet on the baffle wall just above the filter frame for the plenum chamber. Filtered air is drawn across them by a small blower in order to reduce the frequency with which they require cleaning.

These controllers are proportioned, each operating a reversing motor connected to a shaft with six cams for tilting six mercury switches. Three from each group energize relays to control the cold coils; the remaining ones on the thermostat energize heater relays; and on the humidistat, the solenoid valves for the pneumatic spray nozzles. Each mercury switch also operates an indicator lamp, the 12 of them being mounted near the control cabinet to aid in lining up the controls when starting up the system.

OPERATION

Assuming that the room was at standard conditions and that heat absorbed through walls was raising the temperature, the thermostat would cause its related motor to rotate and close the first cold coil switch thus energizing a cold coil relay to open the damper and start the fan. If the cold air introduced into the air stream was not enough to lower the temperature the motor would rotate further to start the second and, if necessary, the third. If meanwhile the amount of cold, dry air issuing from the coils lowered the humidity, the humidistat would respond, also stepwise, to cause its related motor to energize the solenoid valves to add moisture to the air. When equilibrium is again established, both controllers would be in the neutral position and only the main blower would run to circulate the air in the room. In like manner if the humidity were to rise, the cold coils would be started to absorb moisture and if too much cooling resulted the thermostat would act through its system to turn on heaters to compensate. Occasionally when the outside air is near 73°F. and dry, and the humidistat has caused the sprays to operate for some time, the thermostat will energize heater relays to compensate for the heat absorbed in vaporizing the spray water. The operation of the heaters and, except in the rare occurrences noted, of the sprays requires no compensating action by the opposite controller as they perform separate functions, whereas the cold coils both cool and dry the air.

The condensing units for the cold coils do not directly depend upon the thermostat and humidistat but upon their own pressure switches. These are set so that when no air passes through the coil, the resulting drop in suction pressure causes

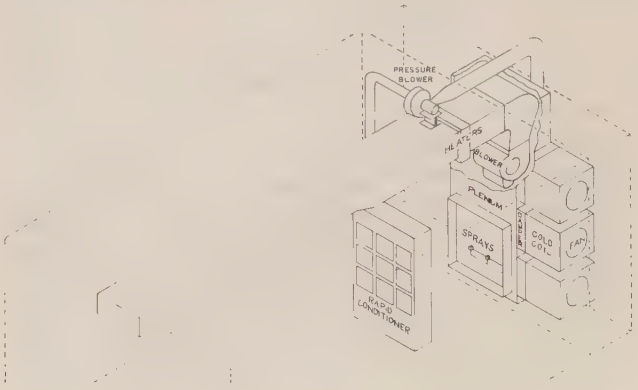

Fig. 2. Arrangement of equipment

the compressor motor to stop. When the coil has warmed up to about 42°F. the compressor starts again and runs until the pressure drops to the level equivalent to a refrigerant temperature of 32°F. As 42°F. must be reached before the compressor starts, any ice formed on the coil will melt before the compressor starts.

The use of this system offers two advantages. First, elements are idle except when needed and only enough elements are operated to maintain conditions. Second, it has been found that, except in cases of extreme outside conditions, the third element is rarely needed so that it is in effect a stand-by unit. Therefore if one of the first two units fails mechanically the third element will carry the load until the failure can be corrected. There can be no doubt that with 24-hr. operation for months at a time this arrangement for maintenance or repair without interruption is a decided advantage.

RAPID CONDITIONING

Rapid conditioning of paper for testing has been practiced in some mills since about 1955 and is accepted as a TAPPI Routine Control Method (*2*). It is done by drawing conditioned air through one or more thicknesses of sample for a short time, the time being dependent on basis weight and porosity. Five minutes is the recommended minimum regardless of how short the theoretical period. General practice is to return the air used to condition the sheets to the room in order to avoid undue load on the conditioning equipment.

The conditioner used in this mill is a plywood box having nine 1-ft. square openings on each side. The samples are supported in these by three plies of wire mesh (40, 10, 2) to prevent wrinkling by air pressure. Suction is provided by a pressure blower on the roof (226 c.f.m. at 6 in. S.P.) and the air removed from the room is returned by a duct through the plenum chamber of the room conditioning system.

Several benefits are derived from rapid conditioning for mill control testing. For example, prior to the use of this method conditioning time for samples hung in the room was 2 hr. as a longer period caused a considerable accumulation of rolls awaiting distribution to storage as satisfactory, to a holding area for retest, or to the broke handling equipment. As this short period is not enough for close approach to equilibrium, results of course were of doubtful value. A most important benefit is that the results are available to the machine crews in some 15 or 20 min. after the reel is sampled. Formerly a lapse of $2^1/_2$ hr. was the custom. As experience was gained in the use of the equipment, it was found that a better sampling and testing schedule could be worked out. The present system is to take a reel sample and test it for the more critical physical tests at five points across the reel. If no point gives results below specifications, all rolls are accepted. If a point or points give low results, the rolls from satisfactory points are accepted and those from the low points are retested individually as soon as possible. Therefore, except in rare instances, not many rolls are accumulated while awaiting test results.

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2. Yundt, A. P., Quick Conditioning of Paper. TAPPI Routine Control Method RC–257, *Tappi* 39, No. 2: 170A (Feb. 1956); *Packaging Abs.* 13: 388; *Printing Abs.* 11: 289; *B.I.P.C.* 26: 561.

Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

Moderator Obenshain: Well, somehow one company has fixed up their test room and it looks very good. I am sure that some of us can go back and maybe improve our own test rooms after hearing this series of papers. Dr. Hobbs, do you have any remarks to open the discussion on this paper?

Dr. Hobbs: There were two remarks that were submitted by R. C. McKee (The Institute of Paper Chemistry), and I think that Mr. Clapp has already answered these in part at least.

One of them indicated that no pickup ducts appear to be used. Have dead zones been observed in the room?

Of course, you have a positive pressure within the room and the doors and the airlock permit passage of air through there so that takes care of the situation.

Mr. Clapp: That is correct and also the three thousand cubic foot blower on two anemostats creates considerable turbulence in the room. There are no dead spots.

Dr. Hobbs: The other comment is that there appears to be no provision for makeup air. You have, however, pointed that out in your oral presentation. That is all I have here, Mr. Chairman.

Moderator Obenshain: Is there anybody else who wants to ask any questions about this? I think Mr. Clapp did an excellent job of presenting this subject and his drawings were very clear. I think we have had excellent slides for this whole symposium.

Our last paper of this group will be given by F. M. Gavan, chairman, Subcommittee 14 on Conditioning and Weathering of ASTM Committee E-1. This paper is entitled, "The Constant Temperature Room as a Testing Facility."

Mr. Gavan is associated with the Armstrong Cork Co. of Lancaster, Pa. He received his A.B. degree in Physics and Mathematics from Dartmouth College. He is a very active member of the ASTM. Mr. Gavan.

The Constant Temperature Room as a Testing Facility

F. M. GAVAN

In planning the new Research and Development Center the Armstrong Cork Co. was influenced in the design of the constant temperature rooms by its long experience with hygroscopic and thermal sensitive materials. The decision was made to provide five interconnecting rooms for the Physical Test Department involving 40 by 80 ft. total space controlled to 70 + 1°F. and 50 + 2% R.H. These conditions were to be maintained under all normal loads and with high outside loads (it was felt that if these standards of precision were met the projected change to 73.4°F. to satisfy ASTM E41 would result in an easily obtainable standard of high precision). Associated with these rooms are one 20 by 20-ft. research constant temperature room and one 10 by 10-ft. low relative humidity spectrographic room used by the analytical department. In addition there is a sixth room in the Physical Test Department used for asphalt tile testing and thermal conductivity work and controlled at 77 + 1°F. and 50 + 2% R.H. All of these eight rooms are conditioned by three 30 h.p. compressors and the humidity is controlled and recorded by the use of Dewcels. The discussion includes some design considerations, the precision desired, the performance obtained, and practical recommendations. Mention is made of a separate sample preparation room where samples are cut and stored in constant temperature conditions while awaiting tests. Illustrations are provided of facilities, instruments, and performance charts.

In order to establish our interest it may be well to recall that the Armstrong Cork Co. began its operations as bottle cork manufacturers just 100 years ago this year. We have progressed since through the manufacture of corkboard insulation and cork composition gaskets to become suppliers of a complete line of thermal insulations; fibrous building boards; resilient floorings; gaskets made of cork, cork and rubber, asbestos, and vegetable fibers; adhesives; bottle closures; and numerous other products. Although the production of articles made of cork or containing cork represents a small percentage of our current business, it is apparent that the company has had a history of the evaluation of materials

F. M. Gavan, Research and Development Center, Armstrong Cork Co., Lancaster, Pa.

Fig. 1. The constant temperature room in use in 1934

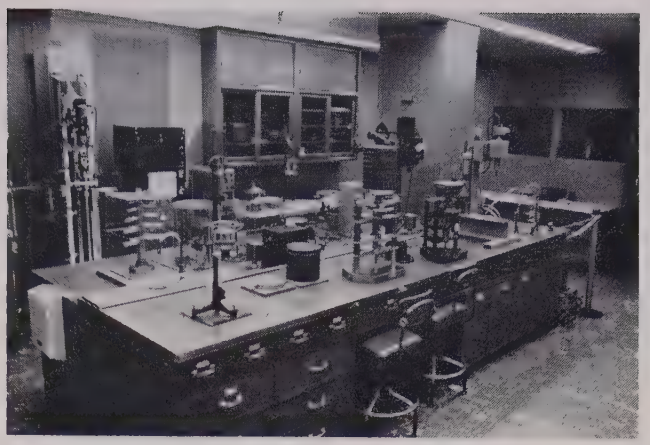


Fig. 3. Industrial division CTR. Note dew point transducers in black box on column

which are highly sensitive to temperature and humidity changes. As early as 1924 a small constant temperature room was in use in our "linoleum plant" located in Lancaster, Pa. When the research laboratories were established in this same area in 1927, another small constant temperature room was built to serve them. The operation of this second room, which is still in use after having been enlarged and considerably modified, is not the subject of this paper but the lessons learned helped to establish the pattern for the content (Fig. 1).

In the course of our preoccupation with precision air conditioning we have noted that some so-called constant temperature rooms are not at all constant, being subjected to frequent interruptions and breakdowns, and do not generally operate within narrow design conditions under all outside influences. Also, inquiries received from those planning to build constant temperature rooms indicate the need for certain information in this respect. It appears that everyone wants a room that works and, since we have been asked about it from time to time, we feel that we can help by providing information as to procurement, construction, and maintenance.

This is not an air conditioning report such as could be supplied by an air conditioning engineer. This is a report on the things that are generally overlooked. As such it does not contain much detail on the mechanics of the system involved and, since it is based on our opinion and experience, there seemed to be no need for a bibliography or extensive references.

First it appears necessary to establish what is wanted. We have found that this is not always clear to all those concerned with constant temperature testing facilities. Therefore, it is necessary to state what is wanted excepting, of course, special environmental rooms with abnormal temperature, pressure, and humidity conditions which are properly the subject of other special papers, have been well covered in the literature, and are paradoxically sometimes easier to obtain than the "ordinary" constant temperature room we are discussing here.

The ordinary constant temperature room must provide an ambient atmosphere controlled to fairly close tolerances so that testing apparatus will perform with reproducible precision and tests made in this atmosphere will be easily translatable in terms of time and geography. The room is only incidentally designed for personal comfort and the standards of control will be those of the industry as listed in the new version of ASTM designation E 41 "The Standard Atmospheres for Conditioning and Testing Materials" which is being prepared by Subcommittee 14 of ASTM committee El. The present standard E 41–48 T (to be split into two parts) states in part "unless otherwise specified the tests may be made in the standard laboratory atmosphere having a relative humidity of 50 ± 2% at a temperature of 23 ± 1.1°C. (73.4 ± 2°F.)." Therefore, in the absence of an industry standard to the contrary the ordinary constant temperature room will be designed

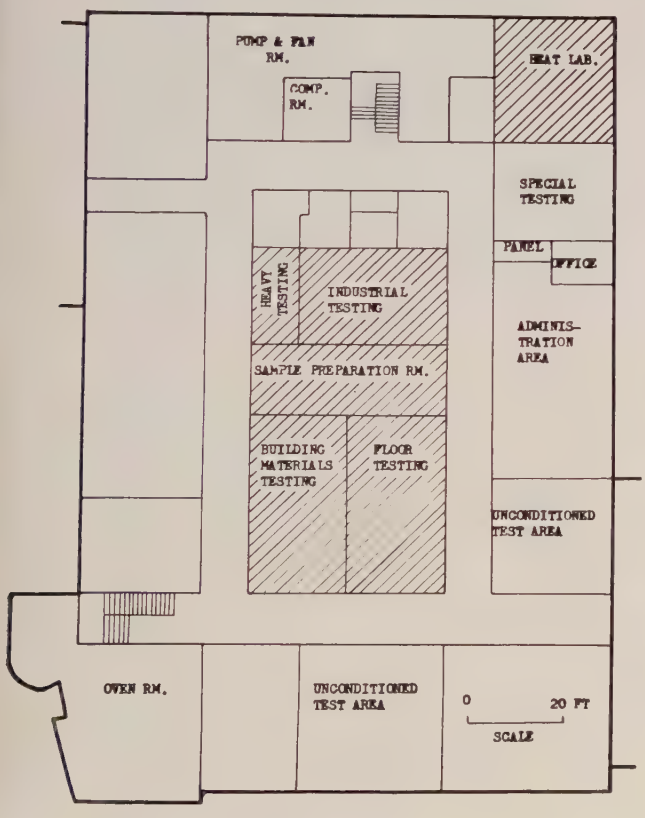


Fig. 2. Arrangement and dimensions of six constant temperature rooms

Fig. 4. Sample preparation CTR

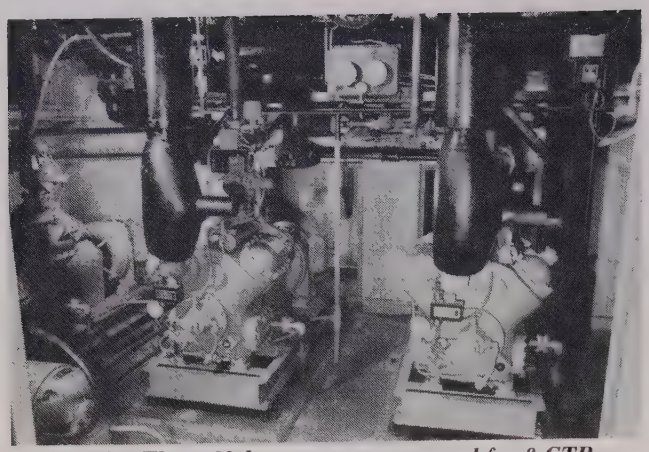


Fig. 5. Three 30-hp. compressors used for 8 CTR

to provide a standard testing atmosphere of 73.4°F. and 50% R.H.

When we came to plan our new research facilities our experience with small, poorly equipped, so-called constant temperature rooms taught us something and we were well prepared with specific recommendations as to our needs. Generally these were:

1. A considerable increase in space (we were planning to more than double our personnel when the new laboratories were occupied).
2. An accessible and efficient arrangement.
3. Constant operation within standard limits for the industry which in our case meant 70 ± 1°F. and 50 ± 2% R.H.
4. Trouble-free, reliable, day in and day out performance.
5. A recording system provided with precision sensing devices so that conditions would be known at all times.
6. Centralized control by means of a composite panel board.

Of all of these considerations the most difficult to get across to the engineer is that of the reliability and precision. Both of these affect greatly the design and expense of the installation so become a tempting approach to the cut which the limitations of the budget always seem to require. The engineer can meet any standard if he can spend the money, but in order to justify the expense and get it done he and those who control the budget must understand what is wanted to the same degree as you do. *We regard this as the most important step in the process of getting a constant temperature room that works.* It requires a constant war against the common assumption that precision temperature and humidity control is just another form of comfort air conditioning. In our case we found it advisable to insure the establishment of

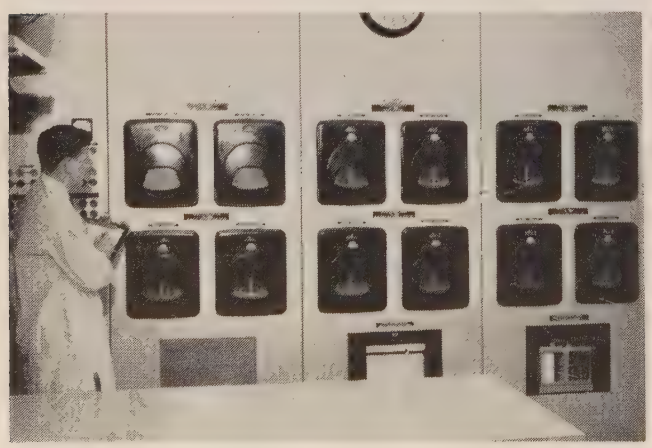


Fig. 6. Central panel board for 6 CTR. Note recorder in lower center. (Barograph, there for convenience only, is not part of CTR system)

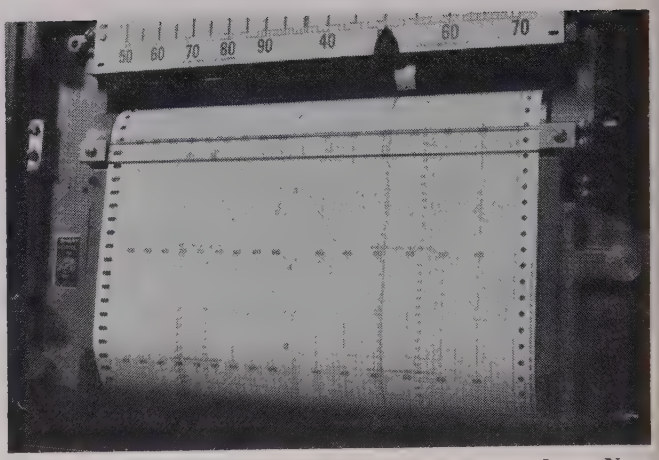


Fig. 7. Room temperature and dew point recorder. Note special test room set at 77°F. and 50% R.H. as also shown in Figs. 10 and 16

the combined point of view by stating in the specifications that under outside weather conditions equal to the design conditions of 95°F. dry bulb and 78°F. wet bulb and, with the normal working load as specified, the rooms had to operate to 70 ± 1°F. and 50 ± 2% R.H. as measured with an ASTM precision thermometer and a standard sling psychrometer operated by laboratory personnel. These requirements, although they included design conditions slightly higher than originally proposed, were accepted by our engineers.

With these things in mind we proceeded toward the construction of five constant temperature rooms arranged as shown in Fig. 2 which also shows the heat laboratory in the upper right and the space allocated for the compressors, the pumps, and the adjacent, unconditioned testing rooms. In addition to these six controlled rooms there are two others which are on the same refrigeration supply; a constant temperature room used by mechanical research and a low humidity dry room used for spectrographic work by the Analytical Department. Because of special considerations the operation of these two rooms is not covered in this paper.

There is one constant temperature room for each of the three divisional sections of the testing department arranged somewhat as shown in Fig. 3. At the end of the Industrial Division room there is a room for the Baldwin Southwark Universal tester and its associated equipment since the noise of breaking heavy samples required this activity to be isolated. Provision for handling long samples was provided by properly locating the doors on either side of the testing machine. In addition to the four rooms already described there is a room for conditioning and preparing test samples (Fig. 4) which also provides room for storing test pieces where they will not be in the way of current operations, and permits conditioning to go on while test specimens are being trimmed.

Fig. 8. Exploded view of a dew point transducer or Dewcel

This sample preparation room has proved to be very popular and efficient and is strongly recommended for inclusion in any program large enough to provide for it.

The Special Tests Section was put into a constant temperature room because it was believed that such apparatus as the ASTM C177 guarded hot plate and the ASTM C201 brick set would work better in a controlled atmosphere. This has been amply borne out by experience.

Ample refrigeration is supplied by two 30 hp. compressors each of which has two steps of control operating in sequence to maintain the chilled water at 42 ± 1°F. The third compressor is for standby purposes (Fig. 5). As far as we know, for reasons of economy, standby equipment is usually not supplied for installations of this type and thus there can be no assurance of constant operation nor is there provision for regular and thorough maintenance. No special arrangements for power failures were made but these are usually of short duration.

The area of the six constant temperature rooms described totals 3600 sq. ft. which is a very sizable figure for this sort of space. The observation and balancing of constant temperature rooms requires special consideration and for this was provided the central panel board shown in Fig. 6 which is located in the Physical Test Department office. There is a pair of indicator controllers for each room and a special recorder with separate sensing elements for a continuous record of temperature and dew point. The special recorder shown in Fig. 7 was made by the then Brown Instrument Co. to print temperature and dew point on the same chart. Temperature signals come from resistance thermometers but the dew point temperature is indicated by Foxboro Dewcels which were selected because we wanted to be relieved of the necessity of changing wicks on wet bulb thermometers. At that time (1951) there appeared to be few engineering firms who were willing to work with this equipment and there seemed to be few examples of the use of the Dewcel as a controlling element for the constant temperature room. We chose to install them, however, and have had excellent experience except that the maintenance of our cells is necessarily more frequent than the manufacturer recommends. We have found it desirable to clean and renew them every 3 months (Fig. 8). The humidity sensing elements for a typical constant temperature room are shown in Fig. 9. These elements are enclosed and baffled to eliminate the effect of drafts and there is a double set of elements in each constant temperature room; one set for control and one set for recording. *We feel that the provision of a recording system is the second most important consideration in the proper operation of a constant temperature room arrangement.* In too many cases the recorder is sacrificed for economy thus destroying the main method of obtaining assurance of performance. The independent record provides a day-to-day means of surveillance of the rooms as well as an overall record such as shown in Fig. 10. From time to time surveys have been made with the sling psychrometer, the Dunmore cell (Fig. 11), and with an aspirator-type pyschrometer (Fig. 12).

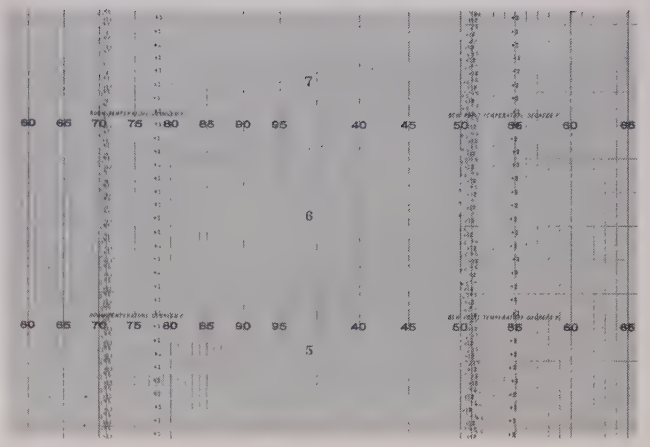


Fig. 10. Typical portion of the chart for March 15, 1959, when outside conditions were equable

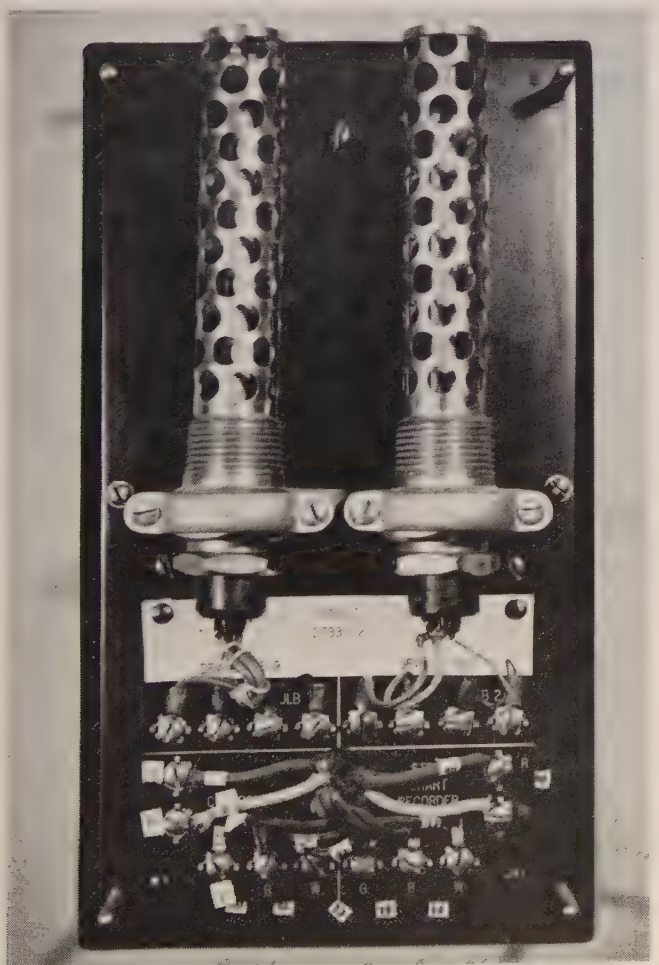


Fig. 9. Two dew point sensing elements mounted on wall. Box cover removed. Temperature elements are in the return air duct

Space does not permit going into the details of all the equipment but it may be of interest to study the view of the pumps and heat exchange apparatus shown in Fig. 13. The rooms were constructed of Hauserman movable partitions, not specially insulated, which were provided with double paned windows so that visitors need not enter the rooms except on special occasions. Although some acoustical correction would have been desirable and is recommended, these rooms are provided with solid pan ceilings because of the necessity of sealing them off at the top level of the partitions.

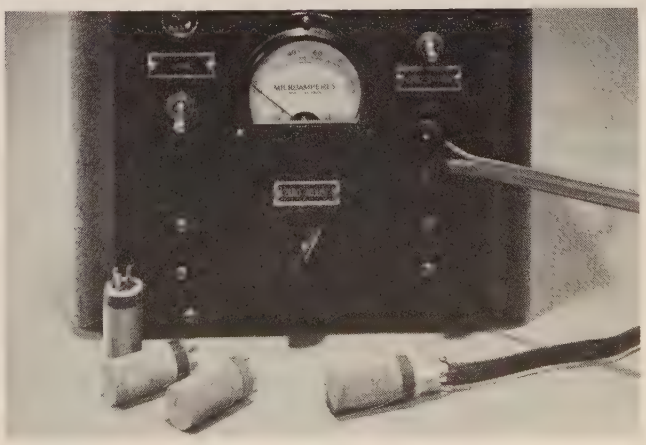


Fig. 11. Four Dunmore relative humidity cells and indicating instrument

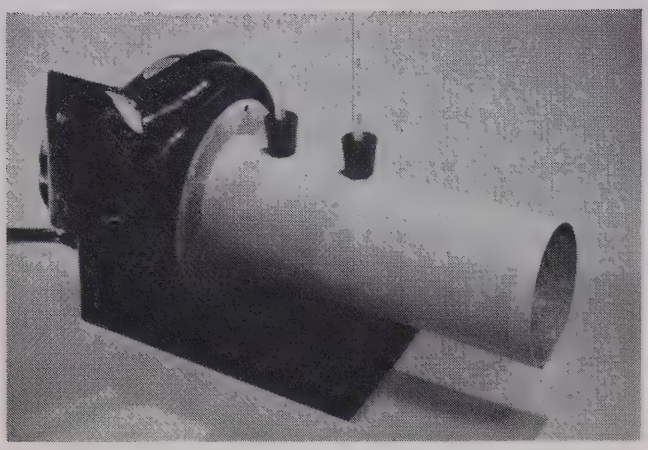


Fig. 12. Laboratory made motor driven aspirator-type psychrometer

This system was started up in November 1951, and during the winter gave indications of good performance. However, with the advent of a very hot and humid summer operational difficulties arose which made it apparent that major changes were required. The improvements, which fortunately were effected, consisted of increasing the heat exchange capacity of the air handling equipment, replacing some control valves with improved precision valves (Fig. 14) which were not available at the time the system was originally designed, revalving the system in some other respects, and making other changes of a minor nature. Later an alarm system was installed by which the boiler room operators can be warned of major trouble (Fig. 15). These men, all of whom are trained labortory technicians, work out of the plant (laboratory) engineer's office and provide 24-hr. surveillance over the equipment. The plant engineer is fully responsible for the maintenance and adjustment of the apparatus controlling these rooms and none of the using personnel is authorized to do anything more than to report the performance as he observes it. *This is regarded as the third essential principle of obtaining constant temperature rooms that work* and we recommend it hightly. We have had excellent results in thus reducing the control of the apparatus to one cook, so to speak.

Assessment of the performance of a constant temperature room which is being used in day-to-day operation of a research laboratory is difficult because of the variation in demands and the difficulty of extrapolating the performance of the whole room from the report of one sensing element. In regards to demands every effort was made to provide extra capacity for the heat load from motors, hot plates, etc., and also from apparatus likely to be obtained in the future. However, as with all things, there must be finite limits and no one is likely to obtain more than a reasonable safety factor in this respect.

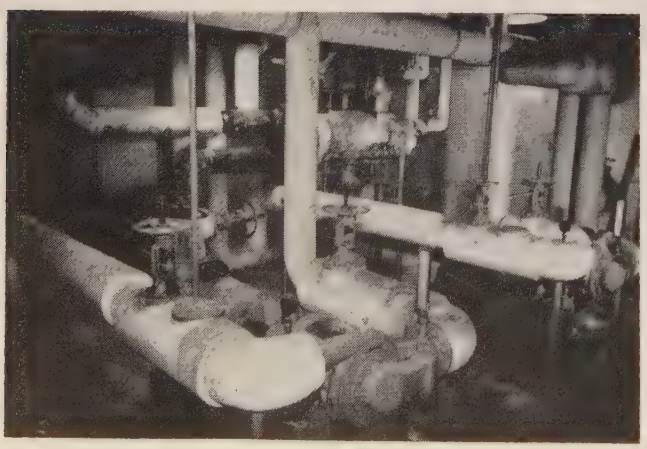


Fig. 13. Pump room with heat exchange apparatus in background

In regards to the location of sensing elements we have found for instance that at one water vapor transmission test location it is necessary to keep an individual spot temperature record if we are to have good data for precision work. However, this is not necessary for most of our water vapor transmission work since sufficient precision is obtained using the conditions measured generally. Successful control of the heat laboratory was not obtained until the optimum position of the sensing and controlling elements was found by trial and error. We have made tests using means of measurement other than the regular sensing elements with results somewhat as obtained during July, 1954, when the maximum outdoor temperature reached 100°F. and ecceeded 90°F. on 3 of the days recorded. The dew point at 8 : 00 a.m. was 60°F. on 7 days during this period and ranged as high as 65° on 2 days. Although the particular room observed (building materials room) did not stay completely within the design limits during all of the period from July 7 to 22, the dry bulb temperature was within ±1°F. during 86% of the time and within 1.2°F. during 95% of the same period. The relative humidity was controlled to within ±2% during 72% of the time, within ±3% for 83% of the period, and within ±4% for 95% of the time. We consider this record and other records of the same sort (which we have) as indicating that we are within the desired conditions of temperature, but fail to meet under all conditions the desired precision in relative humidity. We regard this as acceptable since it indicates that for a major portion of the time we are well within the conditions specified and since we also have limitations on our budget. As a sample of a recorder record during the usual summer high temperature and high humidity conditions enjoyed in Lancaster. Figure 16 indicates that the rooms were behaving very well on Aug. 12, 1959.

Our experience indicates that ±2% at 50% R.H. is difficult to achieve with "ordinary" apparatus. Extraordinary apparatus would be something like putting a constant temperature room inside a constant temperature room and, of course, would greatly increase the expense. In our case our performance will be greatly improved by: (1) the recent installation of overall air conditioning in the building and (2) the impending change of our laboratories to 73.4°F. which should make the dew point precision more easily obtainable. In fact we are quite satisfied after 9 years of performance with the results of this project. Although it was not completely successful on the first go-round this appears to be par for the course, and is nothing to worry about provided corrective measures can be taken as we were able to do. We felt a certain added satisfaction in that our original situation was complicated somewhat by our being only a small part of a major construction effort involving an architectural firm, an engineering construction firm, our own central engineering and architectural departments, and several subcontractors. In addition, the demands of the using personnel, the limitations

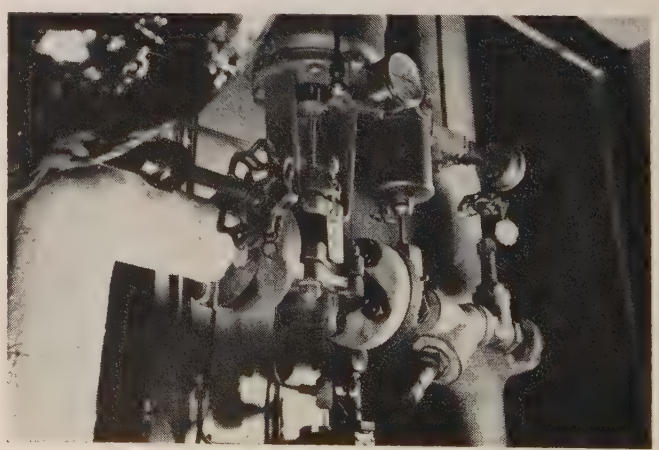


Fig. 14. Precision steam control valve mounted in the machinery cubicle of a typical room

of the budget, and some uncertainty as to requirements exercised their usual effect. We think this explains why success in this field is sometimes elusive unless all concerned thoroughly understand what is required and the using personnel stick to their requirements.

There is only one substantial criticism which has been made of our arrangement. It failed to provide for sufficent room to house the individual air conditioning machinery for each constant temperature room thus making the machinery hard to control, hard to get at, and hard to maintain. Because of the expense and space limitations, correction of the conditions shown in Fig. 17 is almost impossible. In our system each room is individualy air conditioned although supplied from a common refrigeration and heat exchanger. The equipment necessary for a typical room is thus compactly housed and because of the lack of space is very difficult to get at. In planning these rooms we ourselves did not recognize the importance of this item and we now realize that a better arrangement would have been somewhat as in Fig. 18.

Some improvement in performance could also have been obtained by insulating the walls and using refrigerator-type doors but the convenience and versatility we have enjoyed makes us happy that we did not have to put up with them. If you have the capacity, wall insulation is not such a factor as heretofore considered and, if the whole building is air conditioned, capacity is much less of a problem. It is also well, if you can afford it, to install positive pressure blowing out of the rooms so that they will be less influenced by outside conditions. This is a luxury we had to forego.

It appears from our experience that if you want to have a constant temperature room that works you must be prepared to pay for it. But even if you have the money it is necessary to make arrangements with an understanding engineer who

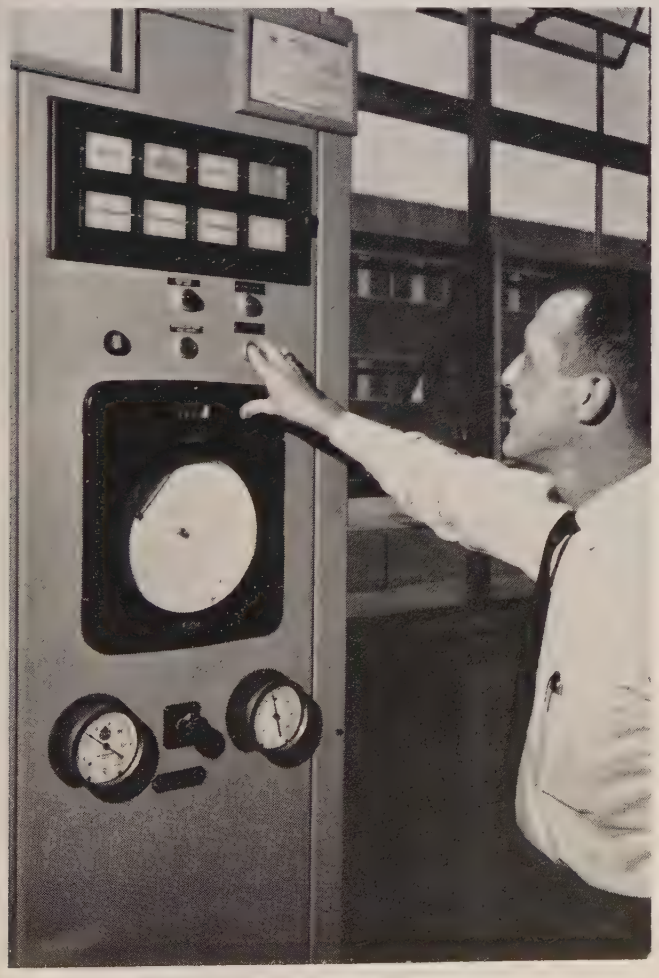


Fig. 15. Alarm panel located in boiler room

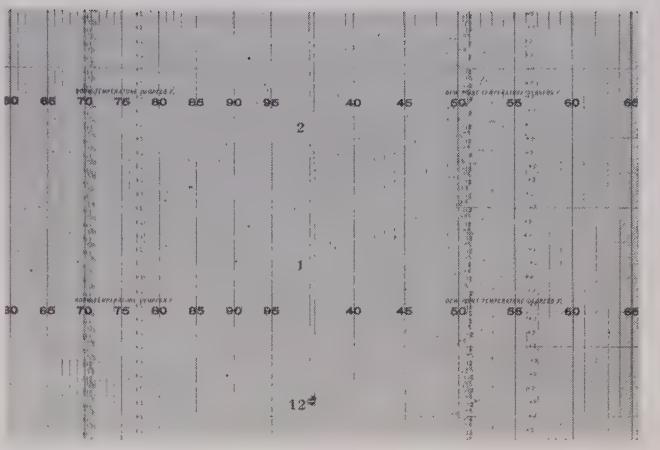


Fig. 16. Typical portion of the record for Aug. 12, 1959, when outside conditions ranged from 63 to 90°F. and 40 to 95% R.H. Cycling of point no. 4 was later corrected by revalving

will be about as enthusiastic for the success of the venture as you are. It is fully realized that the capabilities of installing highly complicated precision equipment have increased greatly in the past 10 years and given the proper amount of money all that I have been talking about would be a mere detail to those connected with space ships and ICBM's. However, the testing engineer or research worker who needs constant ambient conditions generally finds that he has to work within finite economic limits and therefore must go through a process somewhat as we have described. We hope that this little recital of our experiences will tend to help. If you are in a position where you do not enjoy the benefits of a central engineering or architectural department it would be well to employ a consultant who would thus be fully responsible for delivering the performance which you desire and for justifying to you and to the engineering personnel the measures required. Since, as we have explained, various factors affect the cost, an estimate for precision air conditioning is almost indeterminate. It depends for instance on the size: if a constant temperature room is too big, control is difficult and air distribution may be erratic. On the other hand if it is too small surges can be expected everytime the door is opened. Small rooms are affected greatly by variations in the live load while large rooms cost a great deal more. We think that no room constructed by the user should be less than 200 sq. ft. since, in addition to the consideration of control, it must be realized that rooms smaller than this can now be purchased complete and will meet in some cases the most exacting standards. It should also be mentioned that the size is affected by the demands for makeup air which must be kept to a minimum to keep operating expense within limits.

It is then necessary to set high design standards and provide in the specifications a method of inspection for acceptance by thermometer and psychrometer. The rooms should be provided with a separate recorder system, and a centralized panel board to facilitate control and balancing. All considerations of maintenance should be turned over to the plant engineer; however, constant surveillance by the using personnel should be established so that no abnormal condition or malfunctioning is overlooked. Visitors should be encouraged to look through the windows rather than enter the rooms. If necessary a constant temperature room should be made a no smoking area. An important safety feature is to avoid contaminating the enclosed atmospheres with excessive use of solvents and so forth. Another very important item is to insure that the intake to the system is so located that no contaminated air can possibly be drawn into it. Such contamination has happened in several locations that we know of and yet is frequently disregarded. Sinks and water supplies should be kept out of the constant temperature room as far as possible. In our five-room cluster we have just one small

sink with a very small faucet. Sensing elements for recorders should be located away from the control and free from drafts. Emergency exits should be provided. Shutdowns can be avoided by providing proper standby equipment but if they occur unavoidably as in the case of an electrical storm the maintenance personnel must understand how to take the proper measures to avoid condensation. It is easily understood that when condensation takes place everything in the room may have to be taken apart, cleaned, and re-oiled. Since constant temperature rooms are usually in an enclosed location emergency lights should be provided. An alarm system is also necessary so that when the rooms are vacant malfunctioning will be made known to those who are responsible for maintenance. To avoid other unforeseen conditions it appears to be advisable, in the procurement of such an important facility, to build a model if at all possible. This will provide for advance correction for some of the items I have mentioned and will in addition show the necessity of getting a certain number of feet away from that unseen steam pipe which will greatly affect the capacity calculations.

To sum up, if we have good constant temperature rooms, as we think we do this point, we have tried to show that they are the result of experience applied in the design stage, a firm attitude as to requirements, good procedures, and a real interest in the problem on the part of everyone concerned from the mechanics who worked on the original installation to the instrument and boiler room men who are now concerned with the operation. It is fully realized that the art has improved, controllers and sensing devices are more reliable and more precise, and the newer methods of air distribution such as through perforated ceilings will tend to solve this problem as other problems have been solved. However, there appears to

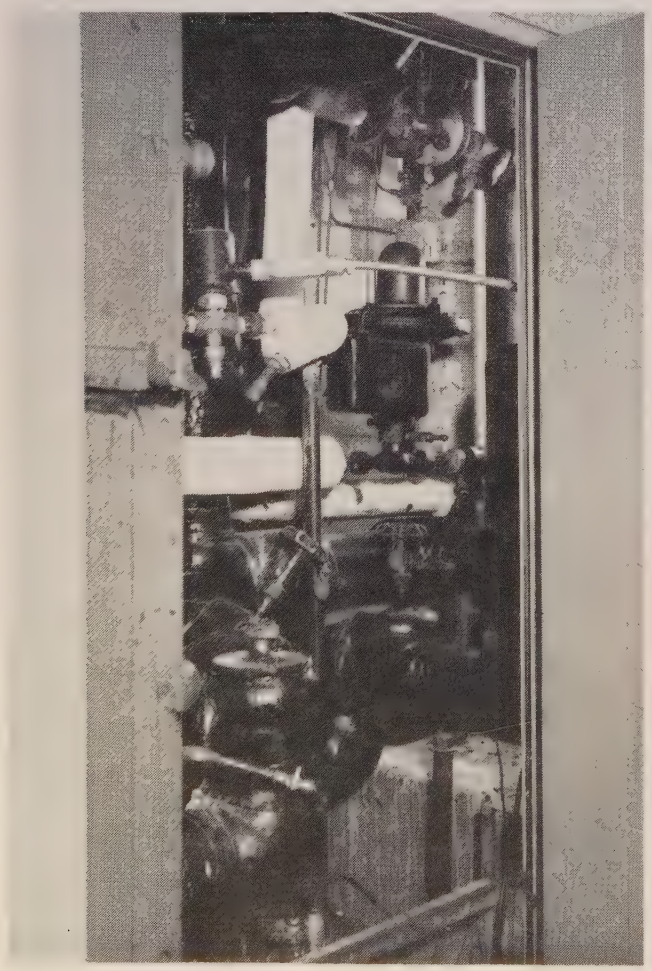


Fig. 17. Crowded conditions in a cubicle housing the air conditioning machinery for a typical room

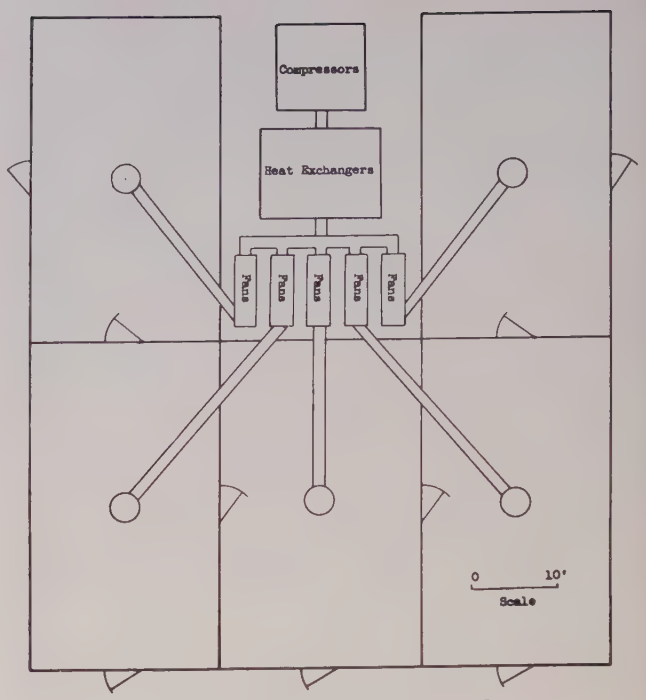


Fig. 18. Schematic diagram of a suggested arrangement of a CTR system

be some need for standards, particularly for the performance of the rooms, and it is gratifying to observe the considerable amount of work being done by technical societies such as TAPPI and ASTM. We hope that this has been of some help to you who are interested in getting new or improved constant temperature facilities and the Armstrong Cork Co. will be glad to furnish detailed information on any of the items mentioned.

Presented at the 11th Testing Conference of the Technical Association of the Pulp and Paper Industry, held in Grand Rapids, Mich., Sept. 27–29, 1960.

The author thanks Messrs. E. D. Scribner, E. H. Donnelly, R. D. Turkington, and C. F. Schneider of the Armstrong Central Engineering Staff, B. R. Abbott the Plant Engineer, Lawton Propst, the Minneapolis-Honeywell, Foxboro, and Riggs Distler Companies for their interest and help, and the Armstrong Cork Co. for permission to publish this material.

CHAIRMAN OBENSHAIN: This paper was very nicely presented and the color of the slides was excellent. Dr. Hobbs, would you like to open the discussion?

DR. HOBBS: I have a question from a friend in Montreal. They would like to ask Mr. Gavan if he has had any experience with lithium chloride type of elements for control purposes.

DR. GAVAN: Well, I don't understand that question because the Dewcel we use is a lithium chloride type of element.

MR. WINK: I wonder whether your friend was referring to the lithium chloride-type humidity sensing element. If he was, then he may have had in mind the sensing element developed by Dunmore at the Bureau. Our experiences with this type of element have been very satisfactory. We have used these elements for many applications, including the control of humidity in our various testing laboratories wherein, in the past, we have operated as low as 20% R.H. and as high as 90% R.H. As a matter of fact, several of our laboratories maintained at 50% R.H. are now controlled with this type of sensing element.

MR. GAVAN: We use Dunmore cells to make supplementary measurements, but feel that the Dewcel is more reliable for long run control.

MR. CHAPMAN (written comment): Our experience with air-conditioning engineers supports that of Mr. Gavan. It seems to be extremely difficult to convince the average air-conditioning engineer that precision of control and reliability of operation are of paramount importance in this type of

installation. It has been our experience that the design engineer is so accustomed to comfort air-conditioning that he is unable to believe that we need the precision which we specify. He also does not want to design for control 365 days of the year. He seems to feel that reasonable control, about 80% of the time, is sufficient. We also agree with Mr. Gavan that recording equipment is not only desirable but definitely essential.

Mr. Gavan: Any form of precision air-conditioning is largely a matter of better standards, better specifications, and better understanding of the people who have to do this thing. Therefore, we say that it is not the air-conditioning engineers who don't want to do what is necessary because they are generally forced to do what can be afforded. These difficulties arise because the people who want the job done don't stick to their guns in regard to precision of standards and the other items detailed in our paper.

Dr. Hobbs: I think I have one comment here most of which has been covered during the day one place or another. However, this one is of interest and it states, "The rate of air flow is equal to 25% of the volume of room per minute and this may be considered a minimum for good control."

Mr. Gavan: That is Dr. Stiehler's remark, of course, he commented in considerable detail and we appreciated that. However, I think we might take just that one item, that it is very desirable to get no-draft ventilation in these rooms. It looks as if this might be achieved with perforated ceilings.

For instance, Dr. Stiehler mentioned that 25% makeup would be required so that in a 20 by 20 by 10 ft. room you would have to have 1000 c.f.m., approximately. With perforated ceilings this could be reduced to 2.5 c.f.m. per sq. ft. of ceiling.

There are many problems in connection with this which I am sure people who have acoustical ceilings are well aware of.

For instance, the plenum chamber has not yet been designed, as far as we know, with the proper openings and the location of openings, and so on. Various people who are aware of this and who are in this line of work are now interested in seeing what can be done about it.

R. D. Stiehler (National Bureau of Standards) (written comment): The paper by Mr. Gavan describes a group of constant temperature rooms that have performed exceptionally well over a number of years. From experience with these rooms, Mr. Gavan points out many aspects that must be considered in designing, constructing, operating, and maintaining a constant temperature room and its associated equipment. It appears to me that several other aspects should be added to those discussed by Mr. Gavan.

1. In addition to constancy of air temperature, it is important that the walls and equipment in the room be at essentially the temperature of the air to avoid effects on the temperature of specimens. In order to have the walls at the same temperatures as the room, it is important to use either an interior room where the outside air does not differ greatly in temperature from that within the room or an exterior room without windows having walls, ceiling, and floor thermally insulated and vapor sealed from the outside environment. Equipment in the room at a temperature appreciably above or below the air temperature can also affect the temperature of specimens under test. Radiation shields around such objects are necessary. In this connection, indirect lighting is desirable to minimize thermal radiation from the lights on the specimens.

2. Another design consideration is the uniformity of temperature and humidity throughout the room. Constancy of conditions at one point is not sufficient. The conditions must be checked throughout the room initially and whenever there is a change in the location of equipment that may affect the air circulation pattern.

3. A large rate of air circulation is important to minimize the difference between the temperature of the entrance and exit air, but drafts are to be avoided. This objective can be achieved through the use of oversized ducts and relatively low air velocities, which incidentally also reduces the noise level in the room. The ideal is to have the entrance air at one limit of the specification and the exit air at the other limit. To achieve this ideal is extremely costly, so there must be a compromise. A rate of air flow equal to 25% of the volume of the room per minute may be considered a minimum for good control; most of this air flow can be recirculated air unless the air becomes contaminated during its passage through the room.

4. Finally, as pointed out by Mr. Gavan, the controlling and recording instruments must be checked occasionally. The wet and dry bulb psychrometer using calibrated thermometers is still the best means of testing the validity of these instruments.

Moderator Obenshain: Do we have any comments from the floor?

Member: How frequently do you have to reactivate your Dewcels?

Mr. Gavan: We clean and renew them every 3 months. I think the manufacturer set 6 months originally but that did not work out for us. That would depend how dirty the atmosphere was and how good the filters were.

Moderator Obenshain: Do we have any other questions? If not, then we are open to questions to any of these gentlemen, who have had prepared papers here this afternoon or this morning. Does anyone have a question?

Member: You have done a lot of talking here about the measurement of relative humidity of the air. I would like to ask whether any of the experts on the speaker's platform today would like to recommend a method of getting accurate measurement of the relative humidity of paper, of a load of paper. I am referring to printing paper. The government, for instance, specifies on many of their lithographic papers that it (the paper) be in equilibrium with air at 50 ± 5% R.H. and I wonder whether it is possible to begin to measure with that accuracy, and if so how.

Moderator Obenshain: Who would like to discuss that?

Mr. Wink: I would like to suggest that you use an electrical device, such as a humidity sensing element based on the principle of the Dunmore element. These sensing elements can be made very small with the amount of moisture sensing material restricted to a small area. This would result in a sensing element of low moisture absorptive capacity, low enough I believe, so that it may not seriously interfere with the accuracy of your measurement. During World War II, when little was known about the water vapor protection offered by flexible wrapping materials, we developed a sword hygrometer utilizing the Dunmore-type sensing element. This sword was designed so that it could be quickly inserted into a package of powdered or granular foods for determining the equilibrium relative humidity of the contents of the package. The moisture content was then determined from the relative humidity, as indicated by the sword hygrometer, and by working through charts showing the relationship between moisture content and relative humidity for the specific foods of interest.

The accuracy with which one may determine the moisture content of a stack of paper by means of the electric hygrometer would depend upon the calibration procedures used and the care taken in establishing the moisture content-relative humidity relationships for the specific papers of interest. The electric hygrometers can be made to operate at high levels of sensitivity and if they are used with reasonable care, to avoid contamination, their reproducibility and stability is good. Hence, under optimum conditions, I would guess that one might be able to determine the moisture content within approximately 0.2% for a specific paper with the electric hygrometer. Equilibrium relative humidity, of course, is only an indirect measure of moisture content. There are occasions in which knowledge of the equilibrium relative humidity is as useful or more useful than knowledge of the moisture content.

B. C. Mays: One of the speakers mentioned the effect of temperature on the moisture content of paper. I wonder if they would repeat that effect. If the temperature goes up, how does that affect the moisture of the paper?

Moderator Obenshain: The absolute moisture content would remain the same.

Mr. Wink: If you are referring to the moisture content at a given relative humidity, then the moisture content would go down as the temperature went up. In other words, at a given relative humidity the moisture content is inversely related to temperature.

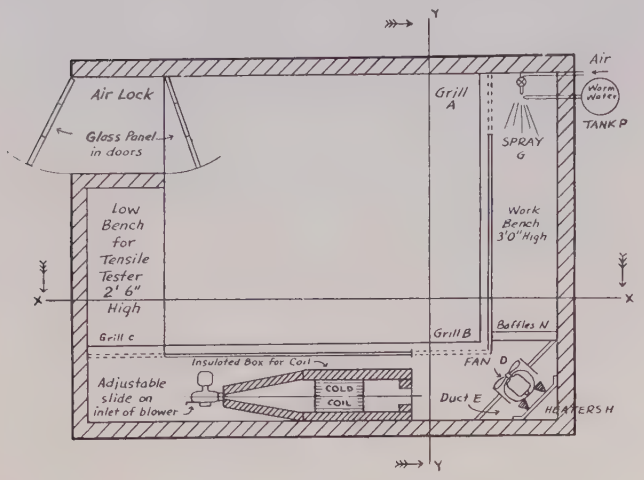


Fig. 1. Plan of room with bench tops removed

Dr. Clark: Gentlemen, I think that you might be interested in again seeing a system we devised a while ago. The first one was made about 35 years ago and worked satisfactorily. The particular system to which Mr. Clapp referred, was developed at the Quartermaster Subsistence Research Laboratory in Chicago and since that time a number of pulp and paper laboratories have adopted it.

I have a slide to show the system again, just to remind you of it. I have just completed building a constant humidity room at Oregon State College and, not having much resources at my disposal, I had to estimate how little it would cost. I built the complete room and fixed it up with benches and have here some charts showing that the humidity doesn't go off more than ±1% at 50 and that the temperature wanders around ±2°F. The entire room cost $2300 complete and, you might take a look at it because it has certain features that makes it rather foolproof and good for operating 24 hr. a day; also because the temperature and humidity controls are separated, many of the troubles with other systems are avoided.

Figure 1 shows a plan of the room and you will see in the right-hand corner a fan blowing air out of a triangular duct which comes up a corner of the room. The duct communicates with the ducts made below the adjacent two benches.

The air comes in at the grill that you see on the lower left-hand side and also through the grill where that spray is. If the humidity and temperature in the room are right nothing happens, the circulating fan blows the air around and it goes to the grills at the floor. In front of the fan is placed a baffle to prevent the air blowing in your face.

As Mr. Gavan explained, if the air is too dry, the sprays come on and if the air is too wet, then the small centrifugal blower moves the air over the cold coil and freezes the water out. If the air is too cold, a heater comes on, which is in the main duct, below the fan, and if the air is too hot, again that centrifugal fan comes on.

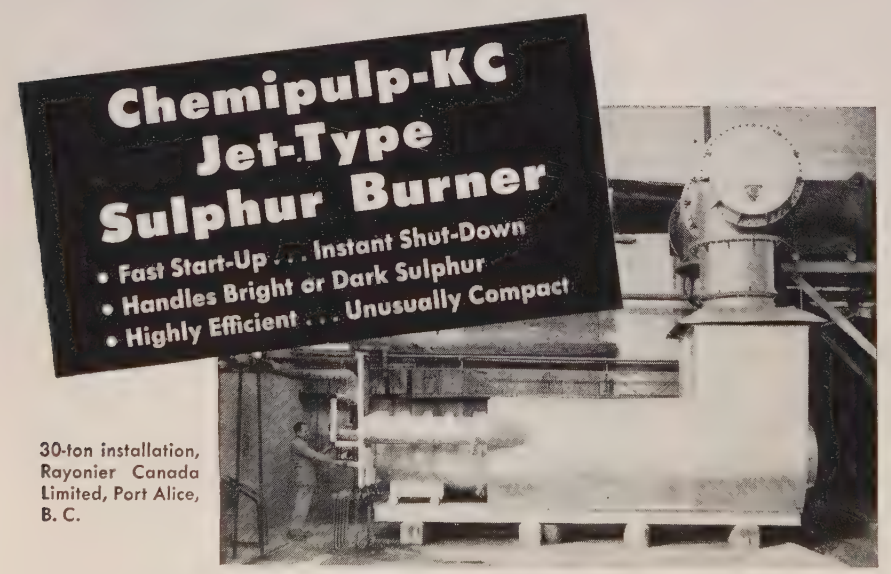
The centrifugal fan is controlled by a humidity controller made by the Brown Instrument Co., and has a neutral point. Therefore, when the humidity is right, nothing happens.

For the temperature control I have two Fenwall thermostats working in opposite ways and set close together so that when the temperature is right, again nothing happens; if the temperature got too hot, one thermostat clicks on and starts the fan; if the air gets too cold, the other closes instead and the heater comes on. If the air is too dry, the spray is started by the hygrostat and if the air is too wet, the fan to the cold coil comes on again.

With this system the equipment is usually lying idle and consequently gives very little trouble. If it does give trouble, the office boy can find out what is wrong with it and correct it.

Moderator Obenshain: Thank you, Dr. Clark.

It seems that we can be fooled by these temperature humidity charts. It depends upon how fast our recording instruments can follow the changes in the room. I have seen some temperature charts and humidity charts that look extremely nice, straight-lines, but when you go around checking a little more precisely, you find out that the room deviates way beyond that, both above and below. The sluggishness of the instrument merely averages out the deviations.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Water Treatment for the Paper Mill Power Plant

HILARY E. BACON and
LEWIS G. VON LOSSBERG

Paper mill water supplies are graded A—D inclusive in descending quality requirements, for boiler feedwater, potable, cooling and maximum flow. Boiler feed specifications are more rigorous at higher pressures and furnace heat release. A 10-year survey of boiler installations shows 650 and 850 psi ranges predominate, higher pressures still a novelty. Zeolite softening (cold and hot) leads feedwater make-up treatment. Demineralization is increasingly popular, but some installations have been unwarranted by the boiler pressures or unsuitable for the primary water supply. Substitution of lower-grade water for some uses is necessary and practical when quantities are limited. Examples are given of direct softening of boiler feedwater without primary treatment. Sea water has been used successfully in pulp manufacture. Saline water conversion prospects are discussed, with brief description of practical processes.

Water for the paper mill power plant includes not only boiler feedwater makeup, but also water for numerous other power plant needs. Quality specifications vary from highest to lowest, including several grades of water for the functions shown in Table I.

Table I. Paper Mill Power Plants Classification of Water Supplies

Grade A:	Boiler feedwater (condensate and makeup)
Grade B:	Potable quality water for feedwater, sanitary and special uses
Grade C:	Cooling water for critical services
Grade D:	Water for maximum flow and minimum quality uses

These steam plant needs are usually filled by drawing on the major high-quality and low-quality mill water supplies. Because of widely prevailing water scarcity and inflated treatment costs, the selection and treatment of water for the paper mill power plant may be a complicated problem.

Engineering design must consider, for each service quality specifications providing a fair balance of operating reliability and costs, resources available to supply each grade of water, substitution of lower grades for some services, and protection of high quality supplies from contamination.

BOILER FEEDWATER (GRADE A)

Quality Specifications

Quality specifications for boiler feedwater are dictated by the boiler operating pressure and the rate of heat release in B.t.u. per hour per square foot of projected area in the furnace. Per cent makeup is a moderating factor in treatment requirements.

Current papers on boiler feedwater treatment customarily begin with a claim that higher and higher boiler pressures impose more rigorous standards for water quality. A review of actual boiler installations in the paper industry over the last ten years does not support this view. Figure 1 shows the

Hilary E. Bacon and Lewis G. von Lossberg, Partners, Sheppard T. Powell and Associates, Consulting Engineers, Baltimore, Md.

Fig. 1. Per cent of steam generating capacity

steam generating capacity installed each year in each of eight pressure classifications. There has been a steady, small addition of low pressure generating capacity to meet direct process needs (under 350 p.s.i.). Apparently, the 350 to 599 and 800 to 999 p.s.i. groups have each accounted for 20 to 30% of the capacity each year, and installations over 1000 p.s.i. have been spotty and limited to a few large-capacity plants. However, the bulk of the capacity has been in the popular 600 to 699 p.s.i. range. Figure 2, in which all installations for 10 years are summed up, shows that this last group accounts for 38.4% of total steam generating capacity and 36% of individual boiler units. In view of this record, specifications for boiler feedwater quality for the pulp and paper industry are dominated by problems peculiar to the 650 p.s.i. boiler, with 850 p.s.i. units running second, and higher pressures so rare as to be exceptional.

Boiler pressure is only one premise supporting conclusions on water quality requirements since, even at 300 p.s.i., the excessively high heat release for which modern furnaces are designed may be accompanied by localized overheating that opens the way to scale and corrosion problems formerly encountered only at 900 p.s.i. and above. Prior to World War II, it was customary to tolerate relatively high concentrations of silica, and considerable sludge formed by internal treatment, at pressures well in excess of 650 p.s.i. However, in recent years the tolerance for suspended and scale-forming

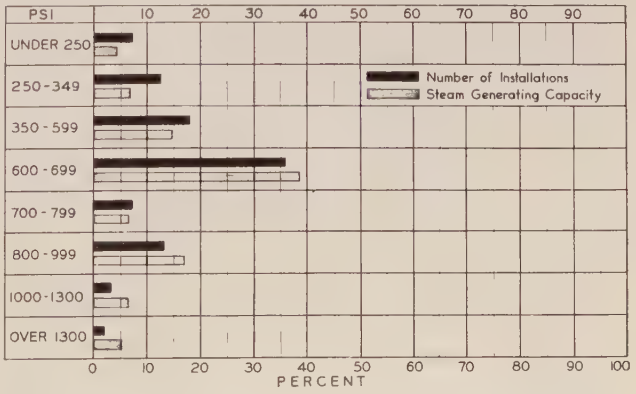


Fig. 2. Paper industry boiler installations 1949–1960

solids has vanished as boilers have become more compact and efficient, and it is basic to sound feedwater treatment practice that all possible softening should be done in the preboiler system.

A review of bound volumes of *Tappi* for the last 10 years reveals that competent authors have presented before this group detailed discussions of modern feedwater makeup treatment methods, complete with flow diagrams and case histories. We refer to the very full Water Session program in 1956, including papers by manufacturers of boilers and treatment (*1*, *2*, *3*), and also leading papers in 1958 (*4*) and 1959 (*5*). It is not proposed to repeat or summarize this information in the present paper. However, for the record, we have collected data on the boiler feedwater makeup treatment equipment sold to the pulp and paper industry in the last 10 years by five leading manufacturers. Table II shows equipment bought for four basic methods of purification: hot process softening, hot zeolite softening, cold zeolite softening, and demineralization.

Table II. Paper Mill Feedwater Treatment Equipment Sales by Five Manufacturers, 1949–60

Hot lime soda	45
Hot zeolite	35
Cold zeolite	62
Demineralization	55

These data do not represent an inventory of feedwater treatment practices in the paper industry since, if plants existing before 1949 were included, hot lime soda softening and cold zeolite softening would far exceed the other methods. However, purchase records over the last 10 years show that demineralization has become more popular than any other process

How is this trend justified by actual requirements for makeup quality specifications?

Typical paper mill power plant feedwater is 30 to 50% treated makeup which should be softened to "zero" (0–2 p.p.m.) hardness and contain the practical minimum of bicarbonate and carbonate to release carbon dioxide in the steam, while buffering the feedwater pH at 8.5 or higher for corrosion control. Prevention of analcite and acmite scales may impose boiler water silica limits of 15 or 5 p.p.m. at the popular 650 and 900 p.s.i. boiler pressures. Considering dilution by condensate, a great many water supplies—especially in New England, South Atlantic, and Pacific Northwest areas—require only simple zeolite softening, occasionally with alkalinity reduction by hydrogen zeolite blend or anion exchange dealkalization. Higher hardness and alkalinity call for hot lime soda or preferably hot lime zeolite softening.

Except for unusual water supplies or critical boilers, demineralization is not generally required for 650 to 900 p.s.i. boilers. Fascination with this novelty has led to the unwarranted installation of some demineralizers for which the raw water is a specific poison, and others for which capital and operating costs far exceed justification.

Above 900 p.s.i. the incidence of water-related operating troubles appears to increase and unless the makeup percentage is low or the raw water quality favorable, a case can often be made for demineralization, usually for silica removal. However, before specifications are written alternate processes should be explored and the feasibility of demineralizing the water supply should be established by sound chemical engineering evaluation supported by commercial experience of other users, or by pilot plant tests.

Resources Available and Substitution of Lower Grades

Water to be softened or demineralized for boiler feed makeup is usually drawn from the grade B source which is coagulated and filtered surface water or clear well water which may, however, require primary lime softening or iron

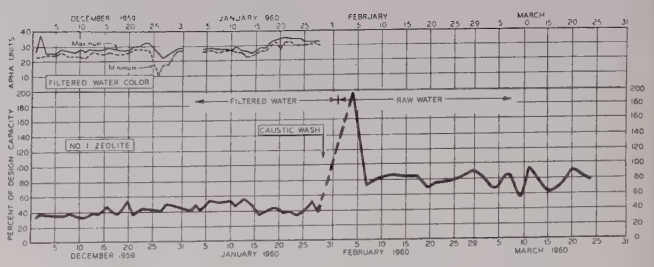


Fig. 3. Effect of coagulated filtered water and raw water on zeolite-softener capacity

removal. This draft on the paper mills' best water supply can often be relieved by pumping raw water direct to a hot lime soda or hot lime zeolite softening plant, which will absorb the burden of turbidity, color, and iron removal and filtration. Properly applied, an activated grade of magnesium oxide supplied through a separate dry feeder will first adsorb color and then silica.

In some cases raw water, without coagulation and filtration, may be applied directly to cation exchangers operated in the sodium or hydrogen cycle with harmless or even beneficial results. Examples known to the authors include:

1. Zeolite softening of St. Mary's river water at Sault Ste. Marie, Ont.
2. Sodium zeolite softening and anion exchange dealkalization of Lake Superior water at Port Arthur, Ont.
3. Sodium zeolite softening of a highly colored pond water at a paper mill in Maine.

In the latter case, after-coagulation of alum depreciated the exchange capacity of the zeolites to 50% or less, especially when water temperatures neared freezing. Substitution of raw water brought a sharp rise in capacity, as shown in Fig. 3. Duration of the test has been too short to warrant final conclusions.

The use of sea water or brackish water as a source of feedwater makeup will be discussed under grade B supplies.

Protection from Contamination

Boiler feedwater for the paper mill power plant is largely condensate from indirect-cooking digesters, recovery plant evaporators, drier rolls, and turbine condensers—in order of ascending purity.

Protection from the more obvious sources of contamination by black liquor in digester and recovery operations is provided by conductivity alarms and automatic dump valves, with which the industry has long been familiar. These devices are not universally effective, either because they are calibrated for resistance rather than conductance, or because the control point is set high enough to keep them from becoming a nuisance to the operators. For this reason we always recommend sample cooling coils and conductivity cells within the power plant, as well as manual dump valves under control of the power plant personnel. Where ammonia, morpholine, or cyclohexylamine are used to adjust condensate pH, conductivity will be deceptively high, and these components are removed in hydrogen cation exchangers. A more elusive type of contamination of paper plant condensate occurs through unauthorized cross-connections with inferior grades of mill water, of which a chronic case is the addition of cold tempering water to condensate receivers to prevent flashing at the pump suction. Figure 4 is a diagrammatic sketch showing how this practice introduced hard water into the boiler feed at one paper mill. This contamination was made harmless by piping zeolite-softened paper from the power plant to the condensate receivers. The cure became worse than the disease because this mixture was highly corrosive by virtue of a high dissolved oxygen concentration, "zero" hardness, and a temperature of 180°. To stop excessive maintenance of the condensate piping and surge tank, and reduce the iron content of the feedwater, a cold water vacuum deaera-

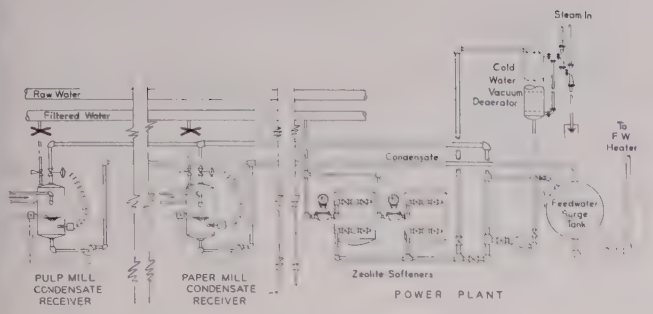


Fig. 4. Equipment for removal of hard water and oxygen from paper plant condensate system

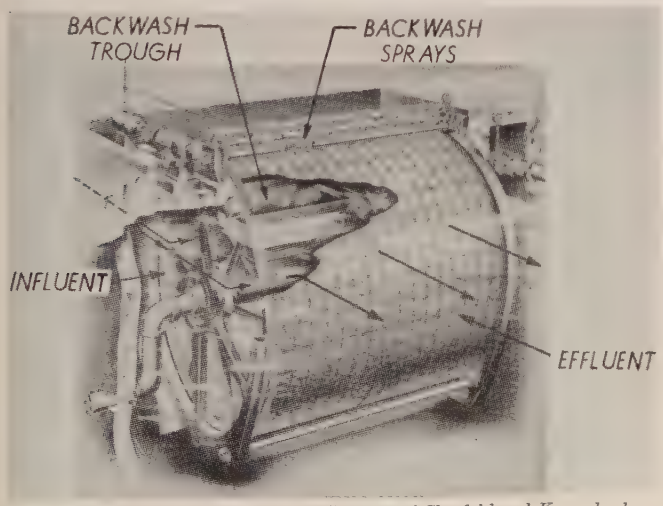
tor was installed to treat the entire zeolite effluent. These additions to the system have been effective and trouble-free.

Most paper mills develop a maze of piping carrying raw and filtered water, steam and condensate, as well as a variety of process liquids. To meet some short-term emergency, connections are made without a thorough study of the consequences. All piping changes should be routed through a central authority that will give permission only after careful study and revision of drawings of record.

FILTERED WATER (GRADE B), CLARIFIED WATER (GRADE C), AND SALINE WATER

Most paper mills manufacturing a quality product require water which is low in turbidity and color, free of iron and manganese, and essentially of public water supply quality. Low hardness and mineral content are desirable but not critical. Coagulated, filtered surface water or clear well water normally furnish this supply, and part of it is usually allotted to the power plant for softening or demineralization to provide feedwater makeup; for laboratory, sanitary, and miscellaneous uses. Production of water of this grade may involve a treatment plant capital cost ranging from $90 to $150 per m.g.d. of capacity. Treatment plants are chronically overloaded and sometimes the water is scarce. Economy or actual necessity motivate the substitution of lower qualities for grade B services, where possible.

It is common practice to provide coagulated and filtered water for grade B services and to divert coagulated water, after settling but before filtration, to grade C requirements such as bearing cooling, makeup to cooling towers, and uses that can tolerate a little turbidity and color. Water of satisfactory quality for these services can often be produced by micro-straining equipment such as is shown in Fig. 5. Currently, 31 micro-strainers are in commercial service or under construction, eight of which are for raw water in paper



Courtesy of Glenfield and Kennedy, Inc.

Fig. 5. Micro-straining filter

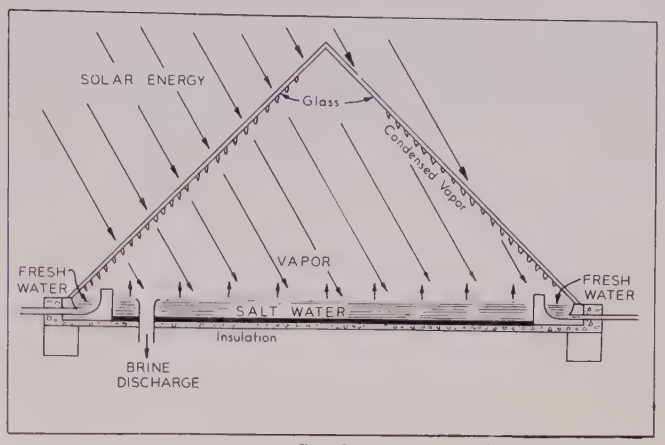


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Fig. 6. Simple solar still

mills, and four for industrial waste effluents in paper mills. The photograph illustrates the flow of water through the center of the cylinder out to the surrounding tank, and the backwash spray above the cylinder which flushes solids from the screen into the receiving troughs. While screens and strainers of this general physical arrangement are not unknown in the paper industry, the particular fabric with apertures of 20, 35, or 60 μ in size is a special feature of this equipment. Its usefulness must be demonstrated by filterability tests before the equipment is purchased.

The most spectacular development in new water resources for such purposes is the use of sea water or brackish water, with or without reduction of salt content. Use of sea water in paper manufacture is not new, according to recently published reports: (1) In Rauma, Finland, one of the paper mills is using Baltic Sea water, 20% as salty as ocean water, to dilute pulp which is screened on Biffar centrifugal screens (*6*). (2) Paper mills located on estuaries in England have for many years employed surface water which consists of an admixture of fresh water and sea water. (3) Full strength water from the North Sea has been adapted to use by Societe Calaisienne des Pates a Papier in pulp manufacture about 1930, because the ground water supply originally contemplated for use could not be developed in adequate quantities. The pulp compares very favorably with the finest pulp on the market with the exception of a slight difference in whiteness (*7*).

In all cases where sea water or brackish water is used, however, it is necessary to resort to resistant materials, such as bronze and special grades of stainless steels, to prevent excessive corrosion and discoloration of the water and product.

The problem of saline water conversion has become vital on a world-wide basis. The United States Government has authorized expenditure of $10,000,000 for demonstration sea water or saline water conversion units, ranging in capacity from 250,000 to 1,000,000 g.p.d. The Office of Saline Water (Department of the Interior) studied 30 conversion processes and has selected four of five demonstration plant sites.*

A few years ago the cost of conversion of sea water by conventional distillation apparatus ranged from $5.00 to $7.00 per 1000 gal. More recently installations have produced water for as low as $1.75 per 1000 gal. It is reliably predicted that the cost of sea water conversion by distillation will soon be 80¢ per 1000 gal. or less.

Minimum thermodynamic energy required for separation of fresh water from the sea is about 2.8 kw.-hr. per 1000 gal. This is true regardless of the process used. It appears that about four times this theoretical minimum is the best that can be hoped for at present. Thus, energy requirements alone for any real sea water process will be approximately 12 kw.-hr. per 1000 gal.

* Recommended by the Site Selection Board of the Office of Saline Water, Sheppard T. Powell, chairman.

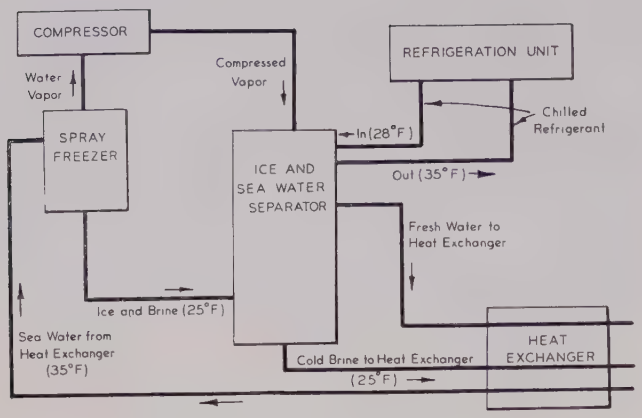

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Fig. 7. Layout of freeze-evaporation process

The most promising processes are: (1) solar heat distillation, (2) separation by freezing, (3) distillation by fuels, and (4) membrane processes (*8*).

A typical solar distillation plant is shown in Fig. 6. Major problems are the high equipment cost and its limitation to areas of intense sunshine and very little overcast. A development by Du Pont utilizing plastics in the design of the solar distillation units makes this method more attractive in areas where it is applicable. One of several processes involving desalting by freezing is shown in Fig. 7. Inherent advantages are: less tendency toward scaling, limited corrosion, lower value of heat of fusion as compared to heat of evaporation, and adaptability to low temperature differentials. Projected construction includes a 15,000 g.p.d. unit being built by the Carrier Corp., and a sizable pilot plant for the Government of Israel in collaboration with American companies.

Figure 8 is a diagram of the electrodialysis process. Upon application of an electric current, cations pass through the cation membrane and anions move in the opposite direction through the anion membrane. Water passing between alternate membranes is depleted of salt, while that passing through

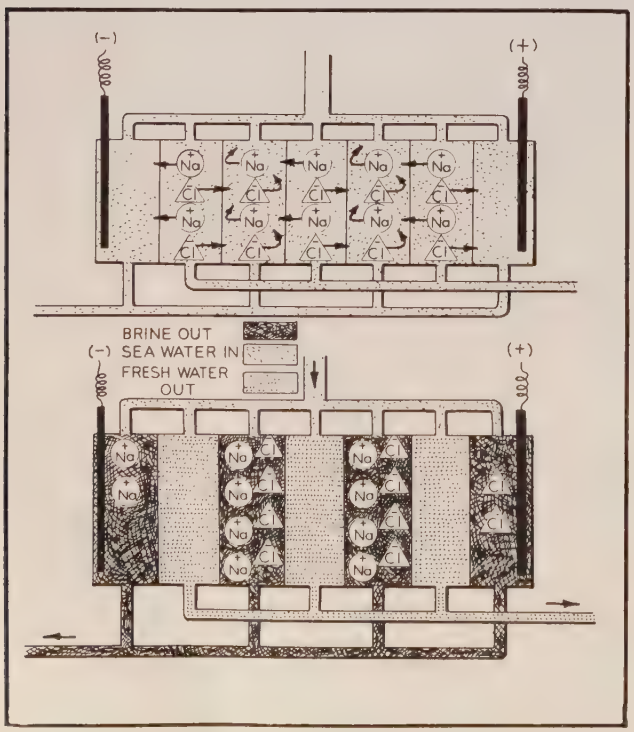

Fig. 8. Diagram of electrodialysis process

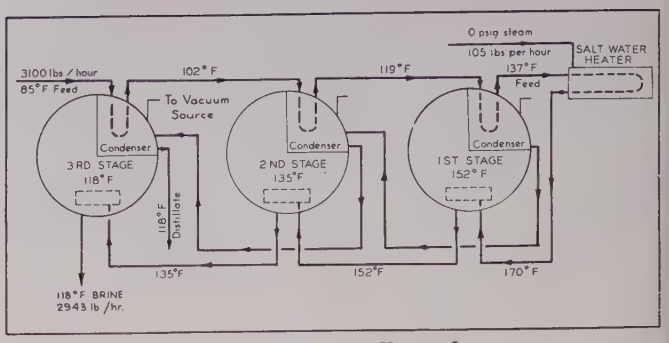

Fig. 9. Flash distilling plant

the intervening pairs of membranes increases in total salinity in amount equivalent to the desalting.

In multistage flash distillation, Fig. 9, the sea water is heated progressively to a temperature of approximately 180°F. It is then flashed to a number of successive chambers operating at progressively lower pressures. The flash from each stage is condensed by the heat exchanger; the incoming water passing through this heat exchanger is in the vapor zone. The Southern California Edison Co. has recently installed a multistage flash distillation plant, capacity 100,000 g.p.d. to utilize the temperature rise of the sea water passing through the turbine condensers.

REQUIREMENTS FOR LARGE VOLUMES OF MINIMUM QUALITY WATER (GRADE D)

Condenser cooling, barking, washing, flushing, and similar services represent requirements for large volumes of water which in general do not need to meet exacting demands as to quality. For the most part either river water or lake water is suitable for such needs after passing through a conventional wire mesh-type traveling screen. As an alternate, rotating drum-type strainers can also be employed for screening such water supplies. Generally bar screens are installed upstream from the finer rotating screening assemblies to protect the wire mesh from damage by large particles of entrained or floating debris.

Special cooling needs, such as supplying incidental small tube heat exchangers and bearings, can be met by closed cycle cooling. In such system, the cooling water is recirculated through a large raw water heat exchanger. This latter unit dissipates the heat from the recirculating water; the coolant may be either ocean water or some other brackish supply of surface or well water. In such systems the recirculated cooling water can be softened and dosed with an inhibitor such as chromates to afford practically complete protection against scale and corrosion. This type arrangement is a special use of a combination of two different grades of waters.

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Presented at the 45th Annual Meeting of The Technical Associations of the Pulp and Paper Industry, held in New York, N. Y., Feb. 23, 1960.

The Outlook of the Control Engineer

DONALD P. MICHEL

To fully utilize the new forms of control that have been made available, the control engineer should raise his sights from the problem of individual control loops to the concept of system controls. The theory of closed loop control can be applied on this broader aspect of the problem. The advantages of this "new look" are a more simplified control system, a more closely controlled variable and a non-interacting loop. Several examples are used to illustrate the problems and their solutions by this concept.

THERE are two problems which have kept control engineers in the pulp and paper industry from advancing toward automation as fast as have our colleagues in the petroleum, chemical, and some other process industries.

Number one . . . the instrumentation, or control engineers in the paper industry have, for the most part, been unable or unwilling to see the forest for the trees. We have concentrated on individual points in a mill or system where instrumentation is needed to control pressure, flow, consistency, or temperature. Instead, a control engineer should consider the "system concept." He should sit back and view the *overall* picture of pulp and paper mill instrumentation or, if you will, automation. He should look at the problem from the viewpoint of how will instrumentation affect product quality, operating efficiency, and company profits. In other words, he should look at it from management's viewpoint.

The second problem is this: management has not given the control engineer enough opportunity to prove himself or the value of pulp and paper mill automation. Perhaps the real reason for this is that management is not interested in the technical details of instrumentation and process control, but only in the economic aspects of it.

Actually, when you get right down to it, as Earl Seagrave, Sr., staff instrumentation consultant of Celanese Corp. of America, once said, the views and problems of the instrument man and management are identical. Both, then, should realize that the concept of automation is a means of controlling, not just a process, but a means of controlling the whole business enterprise. Both should use instrumentation, not just to measure or control temperature, pressure, level, or flow but use it to maximize the company's profits.

MANUAL VERSUS AUTOMATIC CONTROL

Let's look at some examples of how this can work. Take mill A for instance. It was considering installation of a rather sizable, two-stage refining system between the digesters and the bleaching system. Initial tests had shown that such a system would produce a high-grade pulp and do it economically.

The train of equipment was laid out as shown here in Fig. 1. It looks simple and straight-forward. Management of both the mill and the equipment supplier decided that with the exception of the necessary level controls in the chests, consistency controls in the line to the screens, and the usual starting equipment, no automatic controls were necessary. They decided to run the system manually before considering any further instrumentation. But at the time the mill's control engineer was asked to comment on the decision, the materials-handling engineers had produced Fig. 2 showing the possible geographical configuration of the system. One operator and a helper per shift were supposed to be the "brains" of the entire system.

Look at the control engineer's problem in commencing on the plan. Having just two men startup and regulate the system manually would make for a fairly exciting 8-hr. shift. However, once the system had been settled down, the two men could pretty easily handle any small problems that would crop up, like chests spilling over, conveyor plugging, etc. In other words, from the operator's viewpoint, more than two men were needed to manually operate this system and maintain the required degree of pulp quality.

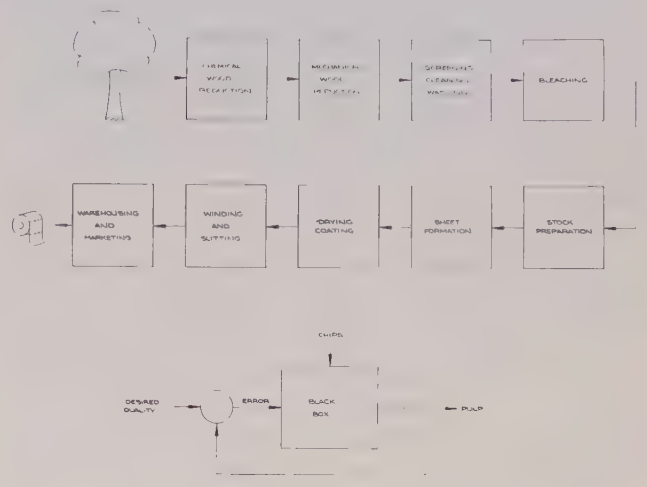

Fig. 1. Block diagram for pulp mill

Can instrumentation help the situation? Yes it can and properly done it can form the nucleus of the completely automated or computer controlled process. A central control room where all the various adjustments can be made and monitored is the first step. Data logging systems, automatic alarms, and television would permit the operator to keep an eye on all the equipment. He could make correction more quickly and catch trouble before it became a serious threat to production.

For the economist in the group, let's say the cost of this automation would be about $30,000 extra. How can the control engineer possibly justify this expense? First of all, it would take at least three men to operate the system manually without the aid of instrumentation as against only two men needed to run the automated system. Thus, one man per shift at a cost of say $5000 would save $15,000 per year in direct labor, and pay off the cost of the controls in 2 years. However, considering the added cost of maintaining the controls and the cost of a higher initial investment, the cost would not be written off for about 4 years. Too long for the average mill management to tie up its capital.

The only way, then, to justify the expense of this automation would be for management to look beyond direct labor savings and consider the other savings and advantages.

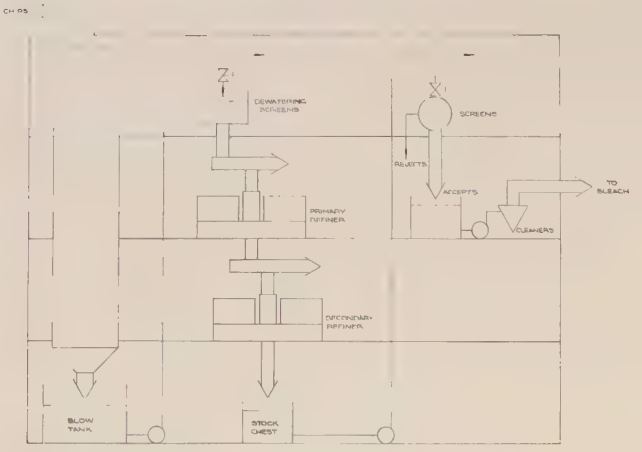

Fig. 2. Typical pulp mill physical layout

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Namely, improved quality of the pulp and increased efficiency of the system because of the elimination—by instrumentation—of off-quality production during startups, less erratic operations, shutdowns, or wasted material and power. Looking at it this way, the expense of instrumentation can be written off in a reasonable length of time.

MANAGEMENT—CONTROL ENGINEER TEAMWORK

How should a pulp or paper mill control engineer and his management approach instrumentation when a new mill, an expansion, or installation of a new system is contemplated?

Management should let the control engineer sit in on preliminary planning meetings concerning plant layout of new equipment. He can do a more effective job this way than he can if he's given a completed engineering plan and told to add the necessary instrumentation.

He can raise his sights and think of controls not as they apply to this corner of the mill or that corner, but as an economical system for the entire mill. He can take the equipment supplied by machinery manufacturers, help place it in the best form to utilize to the fullest the automation that makes sense.

He can look at the black box in his diagram as an entire mill or system. Raw material goes in one end and the finished product comes out the other. Let's assume the control engineer applies a well-planned, smooth-working closed loop control system for the entire paper mill stock preparation system with all machinery under central remote control. Not a glamorous, elaborate instrumentation job—but one that makes sense from an automation standpoint. Even though there, as yet, is no system for continually measuring quality of stock after the driers, he can take individual samples from lab test data, feed it into a computer and check the quality against the standard quality desired by management.

The computer would not only check product quality but would actually make the changes in the system, such as settings of the refiners or changes in the chemical properties going into the digester which affect the quality. Lab data could be periodically fed to the computer to determine what setting to feed into the closed loop control system for the entire mill. This computer controlled plant is possible *now.*

Today we have hydraulically controlled refiners to which air or electrical signals can be sent to make corrections in the refining of the stock. We have adjustable speed drives for feeders. We can adjust the cooking conditions in the digester. Of course, the extra cost of such control equipment can only be justified by the additional amount of on-grade product produced.

We have been relieving the operator's dilemma for years in the immediate areas of flow pressure, temperature, etc., i.e., which way and how much should I turn this valve. Why don't we do it on a plant wide basis?

The use of such control systems would not be stepping on the toes of the pulp or paper mill superintendent. Rather we would be helping him. The computer could make many of the minor changes in settings now being made by the foreman and tour bosses. The superintendent could have a chance to view the overall picture and plan proper corrections, thus saving time and attaining greater accuracy.

Let's look at another example of how properly engineered controls can affect the profits of a paper manufacturer.

Mill B installs a high yield pulp mill including (1) digesters, soaking pits, or impregnators; (2) refiners; (3) screens; (4) cleaners; and (5) thickeners or washers.

Figure 3 shows such an installation, a typical modern pulping system. Let's assume we are the superintendent who runs it. We could expect the paper mill superintendent to be after us constantly, trying to get the right type of stock

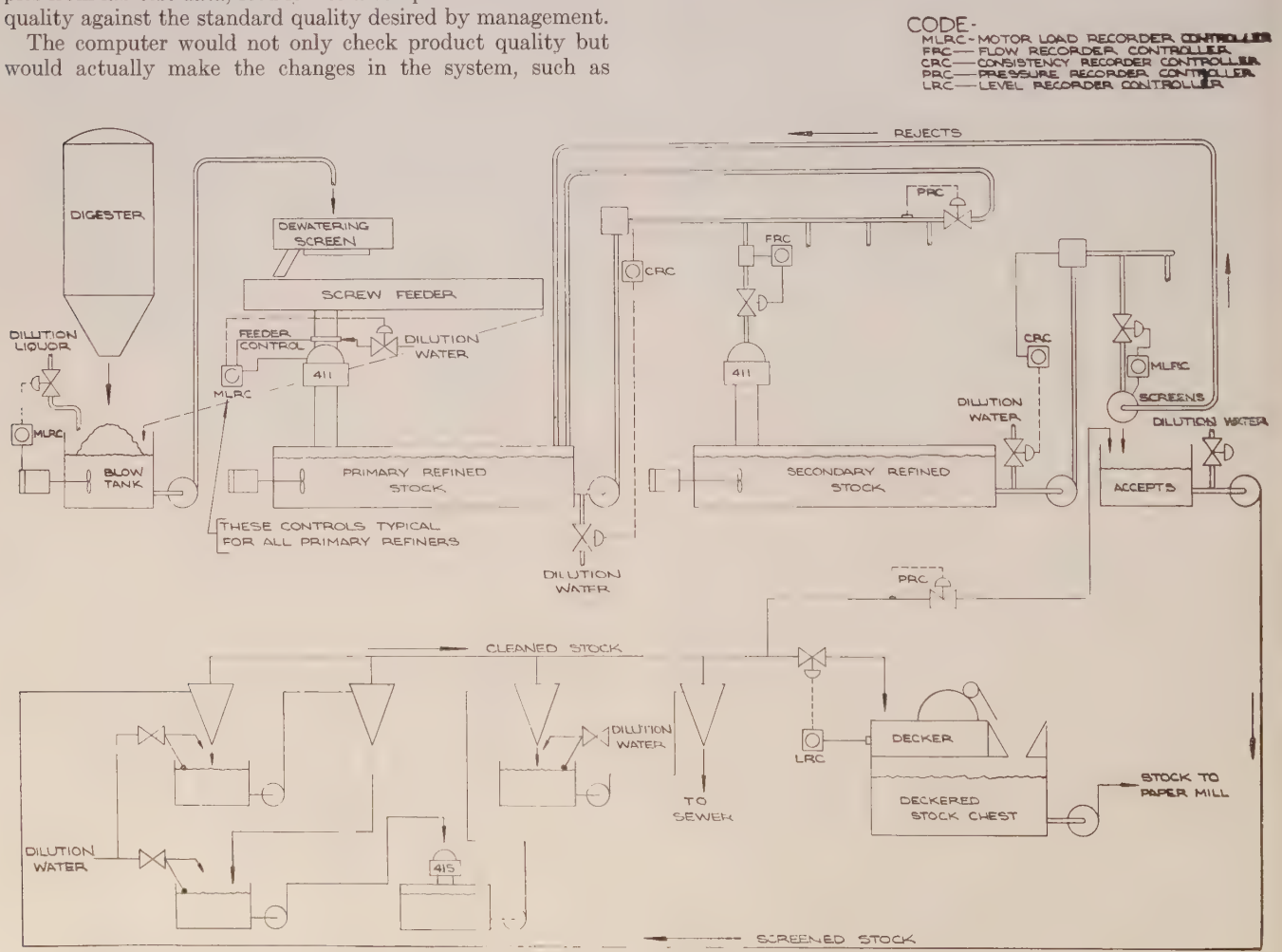

Fig. 3. Basic high yield pulp mill layout

that he needs to make paper. We might as well admit that the stock we get from the blow tanks will vary all over the lot due to changes in raw material, cooking time, temperature, pressures, and the attitude of the digester man toward his wife.

We can expect that each piece of equipment from the smallest valve to the largest refiner will have its own operating characteristics and idiosynchracies. Even the stock chests and pipelines will, at times, seem to have a mind of their own.

As if these were not enough variables to keep an eye on, each operator will have his own ideas on how the train of equipment should perform. And, during all this, it's our job to deliver a continuous flow of stock of the *right* consistency, freeness, color, and test characteristics to the paper mill. Looking at the geographical layout of the equipment in the plant you can see why headaches are the plague of the pulp mill superintendent. Let's assume that this pulp mill is completely modern in every respect except one. Instead of modern instrumentation and closed loop control it has hand valves, handwheels, levers, rods, measuring sticks, pressure gages, and thermometers. Let's startup the equipment.

Once the refiners have been started and checked for proper lubrication, zeroed, and set for the proper openings, the stock pump to the dewater screens can be started. As stock flows to each refiner the feeders must be adjusted, dilution water must be correct and the plate setting changed as the refiners come up to temperature. Meanwhile the chest has started to fill up and, with a 10 to 20 min. capacity, will not allow the operator much time to check the stock from each refiner for final adjustment to the feed or clearance setting.

The secondary refiners, present the same problem and may be slightly more finicky to adjust since the change of flow to one refiner may change the flow to all four. Again, the chest is filling up. The screens, cleaners, deckers, and rejects refiner all need the same amount of attention. Hopeless? No, but a mighty dismal way to run a pulp mill.

If one small detail such as a refiner tripping out, or a stock valve plugging may start a chain reaction which can completely stop production of any particular stage or of the entire pulp mill. By hiring five or six pulp mill operators we may be able to get the mill quieted down and into operation. What kind of economy is this? Who is thinking about the company profits?

Assume now that this pulp mill is, as shown in Fig. 4, with controls and a slightly revised flow layout.

A double-revolving disk refiner used as a primary refiner is equipped with a screw-type feeder with a variable speed drive, a dilution water line, and a load indicator for the main motors. The refiner is generally started up, the plate zeroed and set, the screw feeder started along with the water. After the quality of stock has been checked the refiner is left to run on its own with occasional adjustment being made at the whim and fancy of the operator.

Momentary surges and overloads produce nonuniformity of stock and consistency. These swings, however, are usually averaged out in the primary refiner stock chests. Large overloads, though, can cause the refiner to drop off the line with a resulting loss of production.

If a motor load monitoring device were allowed to readjust the screw feeder speed, the quality of stock coming from a refiner could be much more constant as would the consistency. In other words, the control would be doing a continuous job of readjusting the refiner operation as compared to occasional checking by an overworked operator. This type of operation becomes even more attractive as the number of primary refiners is increased.

By operating the primary refiner as a closed loop system, the amount of rejected or off grade pulp produced will be held to a minimum. If we did this to the secondary refiners also we would have a total refining system which would produce a maximum quantity of on-grade product. By measuring the freeness or drainage rate continuously of the secondary stock and allowing this signal to adjust the loading on the entire bank of secondary refiners we could expect a

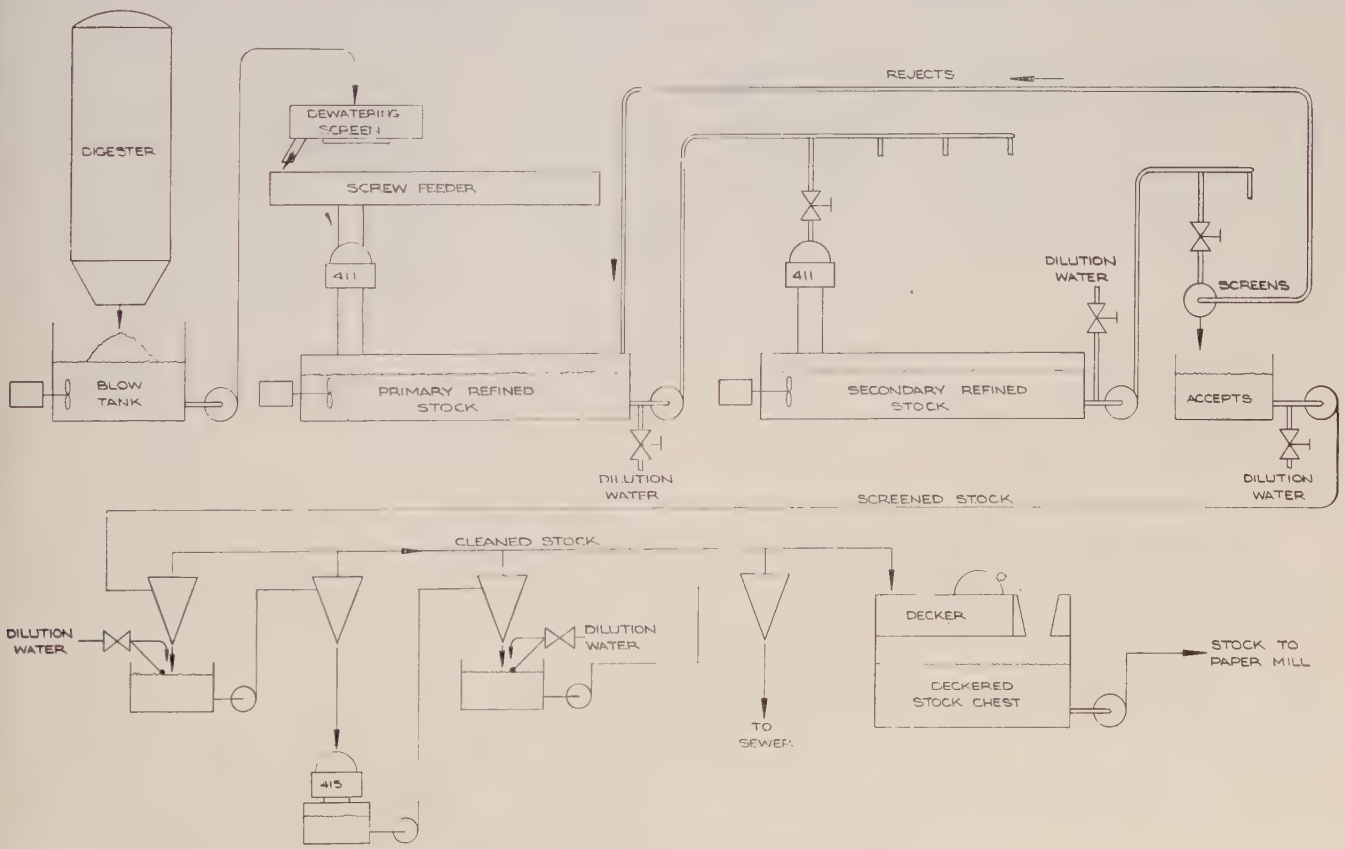

Fig. 4. Basic high yield pulp mill layout with feedback control loops

most uniform product from startup to shutdown. The system would be operating at top efficiency.

SOME ECONOMICS OF THE PROBLEM

Suppose that, in a paper mill averaging a production of 200 tons per day, a properly engineered control system could increase efficiency by just 1%. This would give an increase in output of 2 tons per day. If we sold this at $100 a ton it would amount to $200 a day. Based on a 300-day year we have gained $60,000 a year to apply against the cost of the instrumentation.

If management says, okay prove to us that your closed loop control system actually increases efficiency by 1%. A smart control engineer has records, lots of records to show the difference in how the variables in the operation are controlled. He can use these records to prove his case.

A customer once said to us "Layout a 100 ton per day semi-chemical pulp mill with the works, digester, refiners, stock preparation, screens, cleaners, and after you establish a chain of equipment add all the instrumentation you can."

We did this. We figured out a control system using some equipment that had not yet been perfected. It included an air-conditioned central control room, TV monitors, and every logical control device to make it a perfect automated system. We included a datalogger that would record every single variable in the system on one sheet. When a trend was detected it would be compensated for automatically by the closed loop control.

When customer noted the cost of all this instrumentation we began eliminating all really nonessential items. The datalogger was eliminated for example. The customer ended up with a good, compact, smoothly functioning control system that was a credit to good planning and smart purchasing.

However, had he gone along with the more elaborate system he could easily have justified the extra expense to his stockholders because the equipment would have paid for itself before too long in the form of higher productivity, better quality, and direct labor savings.

CONCLUSIONS

Instrument men are important because only they can give management what it wants in terms of automation. But, the instrument man must approach it by viewing the overall picture and how it relates to the business as a whole. He should explain automation to management, not in technical terms but from the viewpoint of how it affects profits.

The instrument man should strive for simplified but effective controls. Management will be more impressed with a compact, efficient control system that produces than with a glamorous setup.

Finally, let's remember that instrumentation is creative work. Management must give the control engineer time to think and to plan if he is to be effective.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

Evaluation of a Moisture Control

W. O. SMILEY

The value of a moisture control to a paper mill can be determined by comparing "before and after" statistics of speed or tonnage, steam consumption, and lost time. A typical evaluation is presented to serve as a guide. Each of the steps is described to explain its purpose and to assure validity. Definite increase in earnings, reduction in operating costs, and elimination of waste can be indicated by this method of evaluation. From these benefits of the control, shipping, installation, maintenance, and purchase costs are deducted to reveal the net worth of the moisture control to the mill.

A MOISTURE control should be evaluated by some other means than personal opinions to indicate its value to the mill. To installers, to the maintenance department, to some machine operators, and to the laboratory, a moisture control represents added work and responsibilities, and can, therefore, draw some negative criticism. To the quality control department, to the superintendent, to converters, and to the management group, a moisture control can help make a better product with very few changes to the machine. An economic evaluation eliminates prejudices and provides an assessment of the system in terms understood by all at the supervisory level. Management is usually content with the purchase of a control if it can pay out in three to five years. A moisture control fills such a vital role in the papermaking process that it can usually pay out in less than one year.

A successful moisture control is beneficial to a mill in at least five ways:

1. It helps to produce more uniform moistures in the machine direction and also along the cross-machine direction.
2. It reduces production costs: both raw material and processing costs.
3. It increases the salable output of the machine.
4. It improves the overall quality of paper or board.
5. It increases the earnings of a paper company.

The foregoing benefits are derived from: continuous measurement, with recording of moistures across and down the sheet to indicate that production is within specifications (or that it exceeds the manufacturing limits); continuous regulation of a steam valve to control the drying process; better tension control; faster startups; quicker changes; reduced number of breaks; reduced time to recover from breaks; lower steam consumption per ton of paper; reduction of fiber content per ton of paper; higher machine speeds; higher moistures; and more uniform moistures in sheets that sized, coated, calendered, printed, folded, impregnated, etc., so that they suit better the end-use requirements of the paper or board.

One method of evaluating a system is to compare "before and after" samples of the paper to indicate improvement to the process. This method is usually difficult to analyze because of problems in obtaining representative samples, plus the inaccuracies in static testing methods. A paper machine has random short term variations in moisture content that create "noise" for on-the-machine measuring devices. A good way to recognize these random variations is to measure the moistures at 2 to 3 ft. increments in a strip of paper or paper or board 60 ft. long (in the machine direction). Tests have shown that this random variation in the paper and testing method can be ±1% moisture. Any sample taken from the machine may show this "noise" and indicate poor controllability. The standard deviation (SD) is employed to compare large groups of samples, but it is difficult to translate a SD or a correlation coefficient into economic terms.

A better method of evaluating a moisture control employs more easily measured variables of the process than sampling of the paper moisture content. Production records of the machine speed, tonnage, steam flow, time to get the product into acceptable condition at startups, at changes, and after breaks, and a count of the number of breaks yield excellent "before and after" comparisons for determining the value of a new moisture control.

Certain costs are involved in the purchase, installation, operator training, maintenance, and evaluation of a moisture control. Most of these expenses are initial and do not apply after the first year.

Figure 1 is a form that can be used to evaluate a moisture control. It is as dependable as the information fed into the

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M26

Evaluation of Moisture Control System, Mill _____ Machine No. _____
Hurletron Installation No. _____ By _____ Date _____

Compare two 24-hour (or longer) runs with identical grades and weights: one before the Hurletron installation, the other after the control is in full operation. Periods should be for at least 24 hours to include all three shifts.

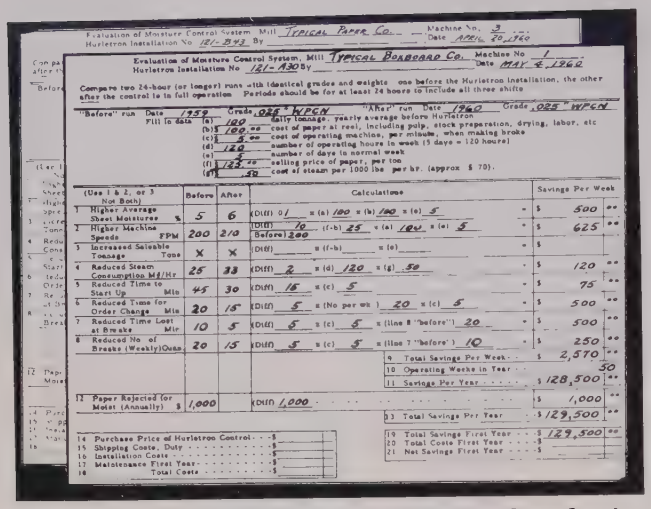
"Before" run: Date _____ Grade _____ "After" run: Date _____ Grade _____

Fill in data:
(a) _____ daily tonnage, yearly average before Hurletron
(b) $ _____ cost of paper at reel, including pulp, stock preparation, drying, labor, etc.
(c) $ _____ cost of operating machine, per minute, when making broke
(d) _____ number of operating hours in week (5 days = 120 hours)
(e) _____ number of days in normal week
(f) $ _____ selling price of paper, per ton
(g) $ _____ cost of steam per 1000 lbs. per hr. (approx. $.70)

(Use 1 & 2, or 3 Not Both)	Before	After	Calculations	Savings Per Week
1. Higher Average Sheet Moistures %			(Diff). 0____ x (a)____ x (b)____ x (e)____ =	$
2. Higher Machine Speeds FPM			(Diff) / (Before) ____ (f-b)____ x (a)____ x (e)____ =	$
3. Increased Saleable Tonnage Tons			(Diff)____ x (f-b)____ x (e)____ =	$
4. Reduced Steam Consumption M#/Hr.			(Diff)____ x (d)____ x (g)____ =	$
5. Reduced Time to Start Up Min			(Diff)____ x (c)____ =	$
6. Reduced Time for Order Change Min			(Diff)____ x (No. per wk.)____ x (c)____ =	$
7. Reduced Time Lost at Breaks Min			(Diff)____ x (c)____ x (line 8 "before")____ =	$
8. Reduced No. of Breaks (Weekly) Quan.			(Diff)____ x (c)____ x (line 7 "before")____ =	$
			9. Total Savings Per Week - - - -	$
			10. Operating Weeks in Year - - - - - - - - - - -	
			11. Savings Per Year - - - - - - - -	$
12. Paper Rejected for Moist. (Annually) $			(Diff)____ -	$

14. Purchase Price of Hurletron Control - - -	$
15. Shipping Costs, Duty - - - - - - - - - - - -	$
16. Installation Costs - - - - - - - - - - - - -	$
17. Maintenance First Year - - - - - - - - - - -	$
18. Total Costs - - - - - - - - - -	$

13. Total Savings Per Year - - - -	$
19. Total Savings First Year - - -	$
20. Total Costs First Year - - - -	$
21. Net Savings First Year - - - -	$



Evaluation of Moisture Control System. Mill TYPICAL PAPER CO. Machine No. 3
Hurletron Installation No 121-343 By _____ Date APRIL 20, 1960

Evaluation of Moisture Control System. Mill TYPICAL BOXBOARD CO. Machine No 1
Hurletron Installation No 121-1300 By _____ Date MAY 4, 1960

Compare two 24-hour (or longer) runs with identical grades and weights one before the Hurletron installation, the other after the control is in full operation. Periods should be for at least 24 hours to include all three shifts

"Before" run Date 1959 Grade .025" WPCN "After" run Date 1960 Grade .025" WPCN
Fill to data (a) 100 daily tonnage, yearly average before Hurletron
(b) $ 100.00 cost of paper at reel, including pulp, stock preparation, drying, labor, etc
(c) $ 5.00 cost of operating machine, per minute, when making broke
(d) 120 number of operating hours in week (5 days = 120 hours)
(e) 50 number of days in normal week
(f) $ 125.00 selling price of paper, per ton
(g) $ .50 cost of steam per 1000 lbs per hr. (approx $ 70).

(Use 1 & 2, or 3 Not Both)	Before	After	Calculations	Savings Per Week
1 Higher Average Sheet Moisture %	5	6	(Diff) 0 / = (a) 100 x (b) 100 x (c) 5	$ 500 **
2 Higher Machine Speeds FPM	200	210	(Diff) 10 (f-b) 25 x (a) 100 x (c) 5	$ 625 **
			Before 200	
3 Increased Saleable Tonnage Tons	X	X	(Diff) _____ = (f-b) _____ = (e) _____	$
4 Reduced Steam Consumption Bd/Hr	25	33	(Diff) 2 = (d) 120 x (g) 50	$ 120 **
5 Reduced Time to Start Up Min	45	30	(Diff) 15 = (c) 5	$ 75 *
6 Reduced Tons for Order Change Min	20	15	(Diff) 5 = (No per wk) 20 x (c) 5	$ 500 **
7 Reduced Time Lost at Breaks Min	10	5	(Diff) 5 = (c) 5 x (line 8 "before") 20	$ 500 **
8 Reduced No of Breaks (Weekly) Ouan	20	15	(Diff) 5 = (c) 5 x (line 7 "before") 10	$ 250 **
			9 Total Savings Per Week	$ 2,570 **
			10 Operating Weeks in Year	50
			11 Savings Per Year	$ 128,500 **
12 Paper Rejected for Moist (Annually) $	1,000		(Diff) 1,000	$ 1,000 **
			13 Total Savings Per Year	$ 129,500 **

14 Purchase Price of Hurletron Control	$
15 Shipping Costs, Duty	$
16 Installation Costs	$
17 Maintenance First Year	$
18 Total Costs	$

19 Total Savings First Year	$ 129,500 **
20 Total Costs First Year	$
21 Net Savings First Year	$

Fig. 1. Form for summarizing economic and production data. Suitable for evaluations of a moisture control on both paper and paperboard operations

calculations. Therefore, all entries should be gathered from reliable sources and by qualified personnel. The control sheet has been filled with a typical evaluation for a machine producing boxboard; however, the sheet also applies to machines producing kraft, tissues, newsprint, writing, specialty papers, etc. All calculations are designed to show annual savings and costs.

EVALUATION

The above comparison of operation "before and after" the moisture control installation should reveal several interesting facts.

1. When moisture content is controlled to a desired setting and no longer varies freely within limits of the specifications, it becomes possible to raise the average toward the upper limit and increase the moisture of the paper with safety. An increase in moisture of at least 1% should be expected. This is offset by a decrease of fiber weight of 1% cutting raw material costs per ton, or allowing greater yield per ton of raw material. Variations in profile can be greatly reduced when the moistures are presented graphically to operators.

2. On a machine previously running "as fast as it could dry," the higher efficiency resulting from the control permits increased operating speeds with the same steam consumption.

3. As overdrying is eliminated and speeds are increased, the output of the machine rises. Furthermore, the quality of the output improves making a higher percentage of the paper salable.

4. Steam consumption is lowered by elimination of overdrying. Uniform moistures reduce tension variations on a sheet allowing tighter draws and improved heat transfer. Improved drying efficiency reduces costs.

5. At startups, the moistures are seen to fluctuate wildly as speeds, weights, drier temperatures, etc., are adjusted for the run. Moisture is measured and controlled from the end of the process and suffers greatly from these upstream changes. Under automatic control, the driers are regulated to offset these changes and when the machine is "lined out," the sheet moisture will be acceptable. Getting the various factors under control in parallel, instead of in series, shortens the startup time considerably. A 15-min. period is almost 1% of a 24-hr. day; thus, a 15-min. gain in running time increases tonnage output 1% as well as cutting waste costs.

6. Order changes are accomplished more quickly with a moisture control. Here again weights, speeds, furnish, etc., require adjustment and with the moisture control compensating for the changes, the paper is brought into specifications sooner.

7. Breaks are very expensive; tonnage is lost, the sheet must br reprocessed, and all the labor, power, and heat to operate the empty machine are wasted. Getting back into full production is speeded greatly by a moisture control.

8. The frequency of breaks is lowered by a moisture control because tension is maintained more uniformly. Without a control, a drier sheet causes greater tension, with better heat transfer, making an even lower moisture, with greater tension, etc., until a flaw in the paper causes a break. Under control, the main steam valve is regulated to hold uniform moisture when load changes, tension changes, etc., occur during the run.

9. Moistures that are outside specifications can upset many web-fed converting operations. Rejections are undesirable to both the converter and the mill. With full time control, and with warning devices in readiness, the paper will be made uniformly under normal conditions. When an emergency develops, the operators will become aware of the duration and deviation of the upset and prevent the off-specification paper leaving the machine room.

SUMMARY

The evaluation described above can be performed at little cost to a mill. Most machine data are collected daily and the cost of operation is known. It will be necessary for management to direct someone to obtain the data and fill the blanks to develop the evaluation. As a reward, the value of the moisture control will be assessed. With this information, decisions can be made regarding improvement, replacement, or whether other machines in the mill should be so equipped.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

Function of Flo-Vac Rotary Suction Box on Fourdrinier Machines

V. C. HILL and C. L. CLARK

The flo-vac, developed by the Beloit Iron Works with the assistance of Clark & Vicario Corp., is a rotary compartmented suction box to replace stationary wire boxes on a fourdrinier machine. Its primary function is to increase wire life, accelerate water removal, reduce fourdrinier drive loads and, in some cases, improve formation. The various sizes and types will be described with specific results from installations on kraft board, kraft paper, bleached board, wallboard, and printing grades. The vacuum pump requirements and method of application on the machine will be described with power requirements reported.

The Flo-Vac is a compartmented rotary suction box designed to replace conventional stationary wire voxes on a fourdrinier machine. A pair of rolls carry an endless, perforated, and grooved belt over the top of the stationary suction box. This rubber belt is driven by the fourdrinier wire. The friction which previously existed between the wire and conventional suction boxes is eliminated. The friction between the wet rubber belt and the stainless steel rotary suction box is only a small per cent of the normal friction between the wire and conventional boxes. The vacuum area in the box may vary in width from 15 to over 100 in., depending on the size of the Flo-Vac and the requirements of the paper machine. The box is designed with one to three compartments to permit controlling the vacuum in each as required.

The basic design of this type of rotary suction box is perhaps 40 years old; however, several design improvements have been made in the Flo-Vac to permit its use on wide

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machines at high speed. A further reduction in friction is accomplished by floating the belt across the boxtop on a film of water under pressure. A means has also been developed for preventing the rewetting of the sheet as the belt quits contact with the wire. A means has also been developed on the larger models for automatically guiding the belt by the use of air guides similar to those used for guiding the wire itself.

The full advantages of rotary suction boxes of this type could not be realized until the advent of high-speed, high-tonnage machines. When the paper industry was producing paper at 700 to 800 f.p.m., or board at 200 to 300 f.p.m., wire life was considered satisfactory. Wires crystallized, fatigued, or were removed from the machine due to damage or corrosion rather than because of being worn out. Water removal on such slow speed machines was not considered a problem and high vacuums now required to accelerate the rate of water removal were unknown.

In more recent years with fine paper machines running up to 200 f.p.m., kraft linerboard machines running at speeds up to 1700 f.p.m., and newsprint machines running up to 2500 f.p.m., water removal at the fourdrinier has been greatly accelerated. Drainage through the wire at the table rolls and wire boxes must be accomplished in less time, thus requiring longer and more costly fourdrinier sections. Also larger diameter couches with wider suction boxes and correspondingly larger vacuum pumps became necessary to accelerate water removal and drive the wire. In recent years secondary headboxes have been applied on board machines, further increasing the water removal problems since the water from the top sheet must be removed through the bottom sheet. Present day speeds and tonnages requiring more suction boxes at higher vacuums have resulted in drastically reduced wire life as well as more lost time for wire changes. The drive load for the fourdrinier section has been materially increased causing still additional strain on wires and necessitating larger diameter couch rolls.

These problems have made it necessary to give further study to the improvement of rotary suction boxes to permit a higher rate of water removal, longer wire life, and reduced drive loads without extending the fourdrinier beyond economic limits. The Flo-Vac is a result of this study.

The Flo-Vac is designed to reduce the drag of the wire over the suction box section. As mentioned before, the endless rubber belt is applied between the wire and the stationary compartmented suction box section since the coefficient of friction between the wet rubber belt and the stainless steel box top is a great deal less than between the wire and conventional boxes. Wire life is increased materially and records indicate reduced drive loads amounting to as much as 50%.

A Flo-Vac is made in four sizes, known as A, B, C, and D models to fit the special needs of individual paper machines. The A, or smallest size, is used on small, narrow, slow speed machines to replace the last one, two or three wire suction boxes. The A model is also applied on insulating or wallboard machines which operate in the speed range of 30 to 75 f.p.m. The B model, or second size, is used on wider, higher speed machines to replace the last three or four wire boxes. The B model would be used on higher speed machines making highly filled sheets such as printing grades, replacing the dry boxes only. The third size, or C model, which has a vacuum area approximately 50 in. long, is applied on bleached board or high density grades. The major effect on these grades has been to increase drainage and permit the use of more water in the sheet. The C model can be used to replace all wire boxes after a secondary headbox. The D model is used on wide kraft linerboard machines or 0.009 semi-chemical machines to replace most or perhaps all wire boxes. This model has the capacity to handle upward of 8000 g.p.m. and volumes of air in excess of 10,000 c.f.m. in a vacuum range from 10 to 22 in. Hg. The vacuum area of the three compartments is over 96 in. long.

On all models water is introduced under the belt between the slots in the box top at 3 to 4 lb. pressure to float and lubricate the belt as it passes across the top of the stainless steel rotary suction box. The stainless steel compartments are made of sufficient depth to provide low air and water velocities to eliminate vacuum losses throughout the passages. In all cases the vacuum measured on the front side of the compartmented box in the Flo-Vac will register the same as the vacuum on the back side so that uniform drainage across the machine is provided. These deep compartments are directly connected to a similar compartmented air water separator on the back side of the machine. This stainless steel CVCO separator is flanged to match the outlet of the Flo-Vac and is provided with barometric leg connections at the bottom and vacuum connections at the top of each compartment. The barometric legs on the first one, or two compartments of the Flo-Vac separator carry the water into the normal wire pit seal box in the basement. The leg from the last compartment may be connected directly to the suction of a centrifugal removal pump to provide a means of carrying vacuums in excess of 20 in. when required, since the barometric leg into the seal box would be of insufficient length to permit carrying such high vacuums. It is possible with the Flo-Vac to carry vacuums up to 22 or 23 in. Hg. This is often desirable in the last compartment to obtain maximum water removal. This supplements the action of the couch permitting the use of narrower suction boxes in the couch where desirable and a possible better ange of take-off from the couch. The narrower couch box reduces the vacuum pump requirements for the couch roll and may permit the use of smaller diameter couches, with the drive load materially reduced in many cases.

On rough papers such as corrugating or kraft linerboard, wire boxes may be entirely removed from the fourdrinier section. On one large kraft linerboard machine making upward of 900 tons per day, a model D Flo-Vac now in use is removing all the water from the discharge of the secondary slice at a rate of approximately 7500 g.p.m. at machine speeds up to 1630 f.p.m. This has made it possible to add as much as 28% top liner with the secondary headbox. Wire life has been increased from 50 to 75%. A second Flo-Vac has been purchased for a similar machine in this mill. It is hoped to use this second Flo-Vac temporarily in series with the existing Flo-Vac on the first machine to replace all wire boxes ahead of the secondary slice to determine the additional value of this arrangement.

Another successful installation is on a wallboard machine. In this case it is an A model, proving the value of high vacuum on this grade. This same company has now ordered a size C with a box approximately 54 in. wide, intending to replace all boxes on another wallboard machine. Consideration is being given to using a weighted dandy roll to further compress the sheet to increase water removal and possibly improve the surface of the board. This is not possible with conventional boxes because of the increased friction load added to already overloaded boxes.

Two size C units have been installed recently with box widths approximately 54 in. wide on bleached foodboard machines. In both instances the quality of the board has been improved since it has been possible to add more water to the sheet at the headbox because water removal has been accelerated. The drive load on one of these machines has been reduced by one third, in both instances the dandy roll is being moved further toward the couch to take advantage of water removal benefits gained from the Flo-Vac. On one of these machines the moisture content of the sheet leaving the Fol-Vac ahead of the couch was measured to be approximately 20 to 22%, almost as dry as you would normally expect the sheet to leave the couch.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

Continuous Freeness Recording Controller

GEORGE A. CHEDOMIR

In this system a sample of thin pulp slurry is pumped into a rectangular tank ahead of a slowly rotating drainage cylinder. Under a constant head the slurry moves toward the cylinder. The fibers adhere to the screen and are carried by the cylinder while the water drains through the fibers and screen to rejoin the fibers discharging from the cylinder in the downstream section of the tank. The restored slurry is returned into the process. At a constant cylinder speed the freeness variations alter the level of the slurry ahead of the cylinder. A bubbler detects this alteration and through a controller corrects the level by operating a flow control valve in the pulp supply line. The flow variations are measured by an orifice in this line and are converted into 3–15 p.s.i. pneumatic signals by a differential pressure transmitter. These signals are recorded in terms of freeness and also are fed to a controller to control the pump refiner at a desired freeness level. The effect of variables other than freeness has been minimized while maintaining a high sensitivity to freeness variations.

Continuous freeness measurement has been a challenging problem for quite a time. A solution of this problem has become more important with the increasing speed of production and a growing demand for more uniform products. The lengthy laboratory methods of testing freeness have fallen behind the advanced pulp refining techniques. The enormous quantities of pulp produced per unit time have required more frequent freeness tests during the processing. Delayed information from these tests has not been reliable enough for use in correcting the refiner settings. Hourly resettings by an approximate guess with sharp changes in the degree of refining have produced a storage of pulp of uneven freeness. The average freeness of the mixture has been maintained close to a desired level but there was always more than one combination of the size of fibers that produced the same freeness average. A continuous freeness recording controller will help to determine and maintain the degree of refining nearly constant at a desired freeness level. It is believed that the close contact with freeness and a tight control of the degree of refining will bring an answer to some puzzling questions along the process line. It shall also encourage some new ideas in exploring the possibilities toward a better final product.

DESCRIPTION OF EQUIPMENT

A continuous freeness recording controller has been developed at the Research and Development Div. of Kimberly-Clark Corp. The instrument was installed in the mill production line and it was evaluated in cooperation with the Bailey Meter Co. One advantage of this system is the simplicity of its design and operation. It consists of a freeness detector tied to several standard instruments that are well known in industry. The operation of the detector resembles that of the fourdrinier wire on the machine. It is a miniature process involving several basic measurements with the freeness as a final result. The operation of the system is described following the pulp flow line in Fig. 1. A continuous small flow of thin pulp slurry is pumped through a $1^1/_2$-in. line into a rectangular tank ahead of a slowly rotating cylinder of fourdrinier wire. Rubber strips around the edges and at the bottom of the cylinder seal the upstream from the downstream section of the tank. The level of pulp slurry ahead of the cylinder is measured by a bubbler and it is maintained approximately constant by a controller that positions a control valve in the sampling line. As the slurry flows toward the cylinder, the fibers adhere to the screen and are carried by

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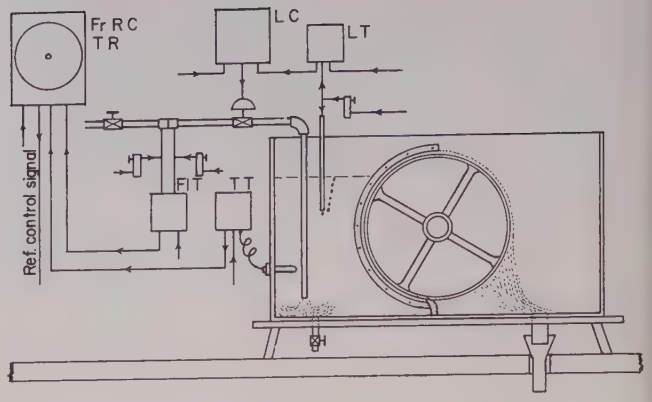

Fig. 1

the cylinder over to the downstream section of the tank while the water drains through the fibers and the screen washing the fibers off the screen into the downstream section. From here the restored slurry is returned into the process. It has been found experimentally that the rate of water drainage through the fibers carried by the cylinder has a definite relation to the freeness of the pulp. Any change of freeness tends to change the level ahead of the cylinder. The bubbler detects this change immediately and through a controller positions a control valve in the sampling line to increase or decrease the flow to the tank. These flow changes are measured by a flow orifice in the sampling line. The flow signal is converted into a 3 to 15 p.s.i. air signal by a differential pressure transmitter. This signal is recorded on a pressure recorder in terms of freeness. It is also fed to a controller and modified to control a pulp refiner at any desired freeness level.

DATA AND THEIR INTERPRETATION

During the development stage of the continuous freeness tester the flow rate was measured in gallons per minute. Curves in Figs. 2 and 3 show gallons per minute versus milliliters Canadian freeness for sulfate pulp and a mixture of sulfate and groundwood pulp, respectively, at a constant consistency and temperature and at several cylinder speeds. These curves indicate that approximately for a 5-ml. freeness change the flow rate has changed by 0.1 g.p.m. A more practical way for recording freeness was adopted when the instrument was installed in the mill operation line. The flow rate units were disregarded and the curves were plotted directly on the per cent chart reading versus milliliters Canadian freeness. At a standard condition based on constant consistency and temperature of the pulp and at a constant cylinder speed samples at various freeness levels were tested and their value marked at the appropriate time and level on the recorder chart. This field calibration, besides being easier, faster, and simpler, also offered more accuracy. Curves in Figs. 7, 8, and 9, based on per cent chart reading versus milliliters

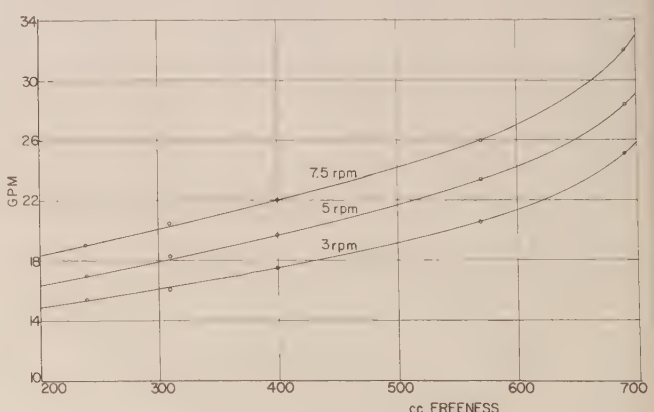

Fig. 2

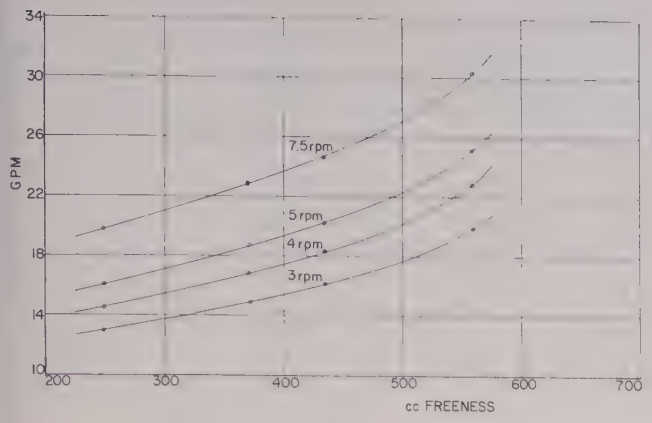

Fig. 3

Canadian freeness were obtained for various types of pulp. In Fig. 7 a curve is plotted for a pulp mixture of 50% groundwood and 50% chemical pulp for the top points of the curve. A mixture of 75% groundwood and 25% chemical pulp was used for middle points, while the bottom points were obtained for 100% groundwood pulp. Scattering was caused by variable consistency (0.230 to 0.300% moisture-free) and temperature (44 to 50°F.) in addition to experimental error. Tests were run at 2.31 r.p.m. cylinder speed.

Figure 8 presents a curve for groundwood pulp at 0.5 to 0.6 moisture-free consistency and 116 to 120°F. temperature variations with the cylinder speed of 7.5 r.p.m. This curve appears linear within the narrow freeness limits between 50 and 70 ml. It can be noticed that this curve and the two of Fig. 7 are found in the upper portion of the recorder chart which indicates that various freeness levels may be recorded at the same chart levels. This flexibility of the system is achieved by the adjustable cylinder speed. The freeness range can be changed by varying the speed of rotation of the cylinder.

Figure 9 presents a curve for semichemical pulp of 0.75 to 0.85% moisture-free consistency and 85 to 88°F. temperature at 3.95 r.p.m. cylinder speed.

Calibration curves can be obtained likewise for all other types of pulp or their mixtures. It is necessary to select a standard condition consisting of nearly constant consistency and temperature of the pulp sample and a constant cylinder speed.

Figure 10 presents freeness variations for 10 hr. manual and 10 hr. automatic control of a refiner by the continuous freeness recording controller. A semichemical pulp was used with the sample of 0.75 to 0.85% moisture-free consistency at 84 to 86°F. and at 3.95 r.p.m. cylinder speed.

SIGNALS FROM VARIABLES OTHER THAN FREENESS

Most of the work done during the development stage of the continuous freeness recorder was to identify the origin of undesired signals in the system and to evaluate their effect on the chart reading. The consistency and the temperature of the pulp sample, the drainage cylinder speed, the pulp

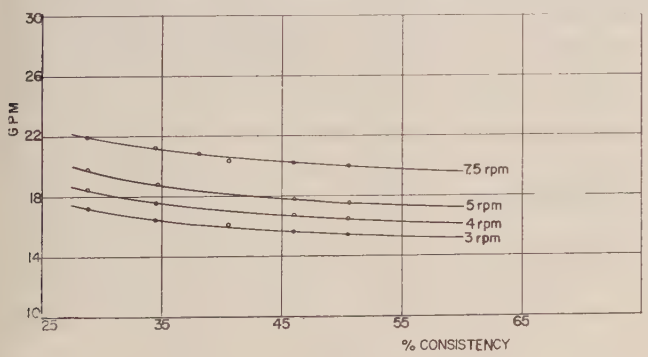

Fig. 4

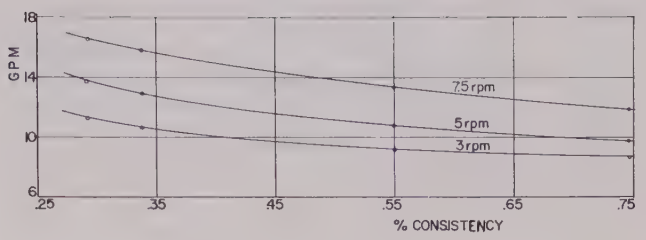

Fig. 5

level ahead of the cylinder, and the type of pulp were assumed to have their effects involved with the freeness reading. Possibilities were explored of measuring freeness variations while holding all of the above variables at a constant level. A constant level of the pulp slurry ahead of the drainage cylinder was selected with respect to proper loading of the cylinder with fibers. This level is maintained nearly constant by a highly efficient level control system. A freeness calibration curve is obtained for each major type of pulp. To maintain a proper load of fibers on the cylinder screen it was necessary to use a sample of thin slurry. The tests proved that for a consistency of over 1% moisture free the fibers of a bulky chemical pulp sample would slide from the cylinder back into the upstream section of the tank. A simple flow ratio method has been applied successfully to supply a continuous sample of a nearly constant low consistency for the freeness detector. The curves in Figs. 4 and 5 show the reaction of the freeness system to consistency variations with all other variables maintained at a nearly constant level. In Fig. 4 curves are plotted for sulfate pulp and 310 ml. freeness, 20°C. pulp temperature and at constant cylinder speed levels of 3, 4, 5, and 7.5 r.p.m. In Fig. 5 the curves represent groundwood pulp at 128 ml. freeness, 20°C., and cylinder speeds of 3, 5, and 7.5 r.p.m. The slope of these curves shows that the consistency effect becomes smaller at higher consistency levels. Ex. A change of ±5% from the consistency level of 0.55% has altered the flow rate by 0.1 g.p.m. The same flow rate change is caused by a 5-ml. freeness change which means that ±1% change from the consistency level of 0.55% has introduced an error of ∓1 ml. in the freeness reading. To approach the true value of freeness and consistency in this work the laboratory test methods were handled with special care. The samples were split and several tests were carried for each point used in the calibration curves. Curves in Fig. 6 were obtained from the recorder chart reading versus pulp temperature for sulfate pulp at 225 ml. freeness, 0.396% moisture-free consistency, and at cylinder speeds of 3, 4, 5, and 7.5 r.p.m. These curves show that for temperature change of 10°C. or 18°F. the flow rate is changed by 0.5 g.p.m. Since this flow rate change corresponds to a freeness change of 25 ml. then 1°F. temperature change will change the freeness reading by 1.4 ml. The temperature effect on freeness reading can be compensated automatically by applying a pneumatic relay to add to or subtract from the

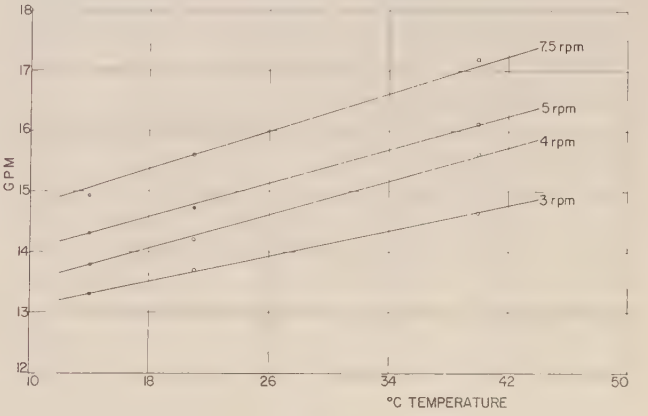

Fig. 6

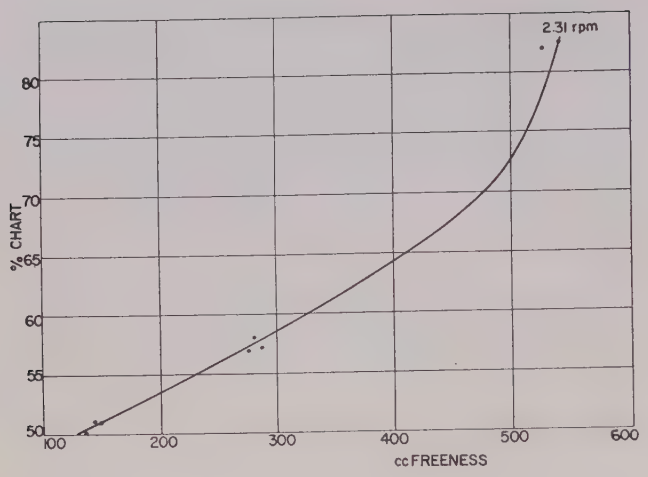

Fig. 7

freeness signal a signal originated by temperature deviations. When these deviations are not too serious the temperature could be recorded by an additional pen on the freeness recorder and the freeness reading could be corrected occasionally for excessive temperature changes.

Special attention was given to the proper loading of the cylinder screen with the fibers. This variable was not measurable and its control caused considerable concern. Various attempts to achieve a continuous and even distribution of fibers on the screen have led to a fairly simple solution. It was necessary to have a fine mixture of pulp slurry ahead of the drainage cylinder. Suitable positioning of the discharge pipe in the tank combined with the air action from the level detecting bubbler and an additional air bubbler have helped solve this problem. The air bubbles rising through the thin pulp slurry have not caused any harmful effect.

It has been shown that the freeness variations could be measured with a high accuracy depending on how closely the signals of the above variables remained constant during the time of freeness measurements. The design of the system offers a wide choice in selecting a standard operating condition. The consistency and temperature of the pulp sample, and the cylinder speed can be selected at various levels, as they come from the process or for improving the performance of the system in one or the other way. At any selected standard condition the freeness is expressed in Canadian standard freeness units. Using a linear recorder chart required a square root extractor between the flow transmitter and the recorder. This extractor was eliminated later because the freeness range was never too wide to introduce a linearity problem.

The per cent chart reading versus milliliters freeness is practically linear within the narrow freeness variations around the desired freeness level. In practice the custom usually is to refine the pulp at a selected constant freeness level and the tendency is to keep the variations small. The resolution of

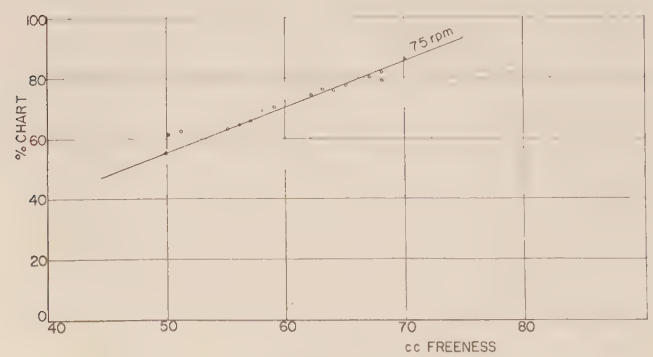

Fig. 8

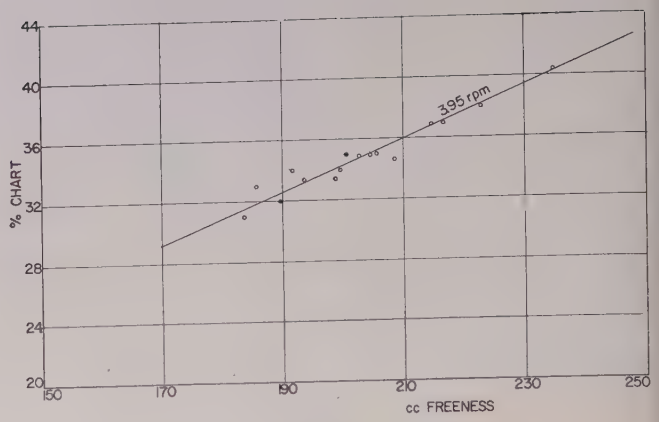

Fig. 9

the freeness reading on the chart can be improved by selecting a higher cylinder speed to raise the freeness carrying flow rate to the upper half of its range, where the flow rate units per unit chart appear widely spread.

MILL OPERATION OF THE CONTINUOUS FREENESS RECORDING CONTROLLER

The recorder has been used on various pulp types and was operated under various conditions in the mill. It has been in continuous operation on a semichemical pulp line for about $1^1/_2$-years. The sample for the freeness detector is obtained immediately downstream of the refiner from a pulp flow line of well-controlled consistency at 3% moisture free. A simple flow ratio method consisting of a positive displacement pump on the pulp line and a flow regulator on the dilution water line is used to supply a continuous sample of about 12 g.p.m. at 0.80% consistency for the freeness detector. Tests showed that the consistency variations remained within 0.75 to 0.80% moisture-free limits, which did not introduce a serious error in the freeness readings. The pulp temperature in the detector varied from 84 to 86°F. The small effect from these temperature variations did not have to be compensated in the freeness readings. It should be mentioned that both consistency and temperature were well balanced at their mid-values for over 75% of the operating time. The system is fully automatic and requires very little maintenance, usually not other than flushing the cylinder screen with water once a week. In case of excessive dirt coming from lubricants or tar in the pulp slurry, more frequent flushing of the screen with hot water or steam would be necessary.

The system is set in operation by starting the pump and cylinder drive motor. Seconds later the pen records the freeness when the pulp sample has reached the preset level ahead of the cylinder. The degree of refining is determined

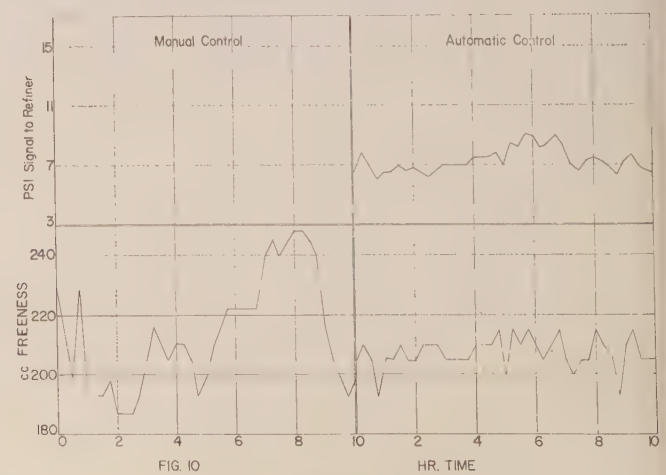

Fig. 10

by moving the control set pointer while observing the recorder pen approach the desired freeness level on the chart.

Once used to the reliable operation of this system, it becomes difficult to return to the time-consuming freeness testing by laboratory methods.

SUMMARY

Under certain standard conditions it was found possible to record freeness in Canadian standard units as a function of flow rate of a sample of thin pulp slurry supplied to a tank ahead of a slow rotating drainage cylinder of fourdrinier wire. At a nearly constant level ahead of the cylinder the slurry flows toward the cylinder. The fibers are carried by the cylinder while the water drains through the fibers and the screen of the cylinder washing the fibers off the screen into the downstream section of the tank. From here the restored slurry is returned into the process. At a constant cylinder speed and at a constant consistency and temperature of the slurry the freeness was recorded with an accuracy better than obtained with the present laboratory methods. The same freeness signal was fed to a controller and modified to control a refiner at a desired freeness level.

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Principles and Uses of Computer Simulation

W. E. WINANS

Simulation is an attempt to imitate the behavior of a system so as to study its reaction to specific changes. Depending on the variety of results extracted, it can provide a very complete picture of the manner in which a system operates. The subject is discussed generally and an inventory system is analyzed as an example.

Simulation is an attempt to imitate the behavior of a system so as to study its reaction to specific changes. It is not a new technique, in general, as physical simulation has been used for many years. The aircraft and shipbuilding industries perform comprehensive scale model testing in tanks and wind tunnels. Architects and industrial engineers made wide use of templates and scale models in layout and design work.

Computer simulation, which is based on a mathematical or logical model rather than a physical one, is more recent. Even here there are examples such as the use of network analyzers to solve electric power engineering problems and the simulation of projectile (or rocket) flight paths that have been done for a number of years. Widespread use of computer simulation, and the accompanying development of methodology, dates from the late 1950's—specifically after the general use and availability of high-speed, stored program digital computers. This is simply because in almost all potential applications of simulation there is too great a volume of logical, numerical, and bookkeeping operations to permit feasible solution by manual methods. The growing use of computer simulation is based on its ability to determine effects of introducing specific changes to a system easier, cheaper, and faster than trial-and-error methods requiring actual change to operating policies and physical facilities. In this sense, computer simulation is an extension or subsitutute for laboratory experimentation, and, as such, its results permit one to test hypotheses, establish feasibility, demonstrate or verify new ideas, compare alternatives, and gain insight into the workings of the sysrem.

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Computer simulation can be used in both the synthesis and analysis of systems. Analysis assumes that the overall behavior of the complete system is known and that the problem is determining the unknown behavior of the individual parts of the system. Synthesis assumes that the individual components of the system can be adequately defined and the problem is to determine the behavior of the system as a whole. Most of the work to date has involved the synthetic use of simulation although the technique of analytic simulation has been used to obtain adequate descriptions of certain components of a system to permit the synthesis of the whole system.

What about the construction of the mathematic or logic model that is the core of this simulation technique? This is frequently a relatively simple process and one that requires an understanding of the logic of the system to be studied rather than familiarity with higher mathematics. Take, for example, the problem of determining how many repair men are required to service a given group of machines. This is a cost-balancing problem where one of the costs, the number of repairmen, can be varied and it is necessary to determine the corresponding cost of machine downtime. There are two basic elements that define the amount of machine downtime. These are the frequency of breakdown and the length of time that machines are idle after they break down.

The length of machine idle time also has two components: the time required to repair the machine and the time required waiting for a repairman to become available. As with almost all computer simulation problems, this problem is a question of what happens to the system over a period of time. It is, therefore, necessary to define the variables on the basis of a time increment. This time increment varies with the type of problem—it could be minutes or seconds for a process control model or days or even months for an inventory control model. In this problem a time increment of an hour would appear satisfactory. Therefore, historical records can be examined to determine first the number of machine breakdowns expected on the average in an hour and secondly, the actual repair time in hours required to put a machine back in service. The actual repair time in hours required to put a machine back in service. The other time element; namely, machine idle time while waiting for a repairman, will be the result of the system simulation as the number of repairmen is varied.

In order to examine a technique that is a basic part of many system simulations, the following data are given as an example of the information that would be obtained for a specific repairman simulation. There is a group of 15 machines and the historical records indicate that there is one change in ten that a machine will break down in any given hour. Further examination of the records indicates the following repair experience:

Time to fix, hr.	*Occurrence, %*
1	40
2	30
3	20
4	10

If the simulation is to yield true results, this pattern must be reproduced by the model. This is accomplished by what is termed the Monte Carlo method. Basically, this is the establishment of some pattern of examining random numbers so that repeated use of this pattern will create a time sequence of events that matches actual experience.

Random numbers can be generated in digital computers by available methods or tables of random numbers (such as "A Million Random Digits," by The Rand Corp.) may be used. Using the following column of digits from such a table, the method of arriving at one hour's experience for the example will be shown.

Random number table

21397
54696
56630
78248

Knowing that a breakdown on a given machine occurs 10% of the time in a given hour, this can be represented by arbitrarily selecting one of the ten digits (0 through 9), say 9, as representing a breakdown. Then to determine the number of breakdowns occurring in the first hour, 15 random digits are examined (one for each machine) and the number of 9's, or breakdowns, are counted. Looking at the first 15 digits of the random number

21397
54696
56630

shows that two breakdowns (digit 9) occurred.

Next, another arbitrary assignment of digits is made to represent the possible lengths of time required to repair a machine.

Digits	*Occurrence, %*	*Time to fix, hr*
1, 2, 3, 4	40	1
5, 6, 7	30	2
8, 9	20	3
0	10	4

Following this pattern, the next two random digits of the table (one for each breakdown) are examined, 78248. This indicates that one breakdown will require two hours to fix and the other three hours. The simulation then proceeds by assigning one repairman to the first breakdown, thus removing him from availability for two hours, and a second repairman to the other breakdown, removing him from availability for three hours. Another hour's experience is then examined for breakdowns as above. If another breakdown occurs and there were only two repairmen, then the machine must remain idle for an hour before a repairman will be available to service it.

The simulation proceeds in this fashion until sufficient hours have been examined to allow comparison of the results obtained with different numbers of repairmen specified. The result in this case is simply the record of the time machines are kept waiting for service. This figure together with the cost of the corresponding number of repairmen is sufficient to permit a decision as to the best size of the repair crew. As an illustration of the flexibility of the simulation solution technique, a record could also be kept to determine the amount of time that repairmen are idle under different crew sizes.

This same model would permit the testing of other ideas such as giving priority to certain classes of repairs or purchasing more reliable equipment.

This example, together with the simulation of a simplified Inventory Control System (Appendix) form a background for the basic considerations in performing a computer simulation. A model must be created which provides a formal statement of the system's behavior. This is accomplished by breaking the system down into a set of elements for which some rule of behavior can be stated and the interactions between which can be described. The behavior of an element does not have to be deterministic if its different possible actions can be defined by a probability of occurrence. In addition the interactions, if any, do not have to be stated in a form permitting analytic solutions as simulation techniques permit handling of complex, nonlinear relations. Approximation or fitting techniques can be used on certain of the elements to secure the best fit between the model and the world it is intended to describe. Actually, this is one of the key factors in computer simulation, rarely is a given problem concerned with all the characteristics of the real system. Very often the essential results are best obtained without considering a number of elements of the system which might add realism at the expense of obscuring the significance of the results. It is also possible to achieve results by restricting the size or scope of the model, as using only a few inventory items in arriving at an inventory policy and then studying the effect of the number of items on these policies by increasing the number included in the model.

Another factor to consider is the time element. It is a very significant part of simulation in that it allows departure from static methods of analysis. However, the decision on the time increment, or scale, to be used could have a significant effect on the results. For instance, changing the period of analysis in the repairman problem from one hour to one-half hour could alter the availability of repairmen at a given time. Doing this would double the length of the simulation to cover the same time span so this necessitates balancing the accuracy of the results with the cost of simulation.

After the model is complete it should be tested with a situation that has occurred in the real system. If the simulated performance does not compare with the actual recorded performance, it means that: (1) some factors that contribute to system behavior have not been discovered, (2) the interactions of all factors have not been described accurately enough, (3) the time unit is not small enough, or, (4) the input to the simulation was not identical to the input to the real-life situation. Adjustments to the model must be made until the simulation reacts as the real system.

Finally, it should be recognized that the model is "run" rather than solved. The results are a description of the performance of a specific configuration of the system. Depending on the variety of results extracted from the simulation it can provide a very complete picture of the manner in which the system operates. Solution, or optimization of results, can be achieved by varying the configuration in search of a maximum of performance. This can be done automatically as an adjunct to computer solution providing definite criteria can be established to identify the "best" result.

The uses of simulation are many but certain general areas can be outlined indicating problems that are being solved today:

Determination of the correct balance of productive capacity with inventories.
Inventory control and distribution policies.
Equipment purchases and plant location.
Machine or equipment design.
Statistical experiments, including replication, which are not feasible on the real systems.

Perhaps the most fascinating aspect of simulation is the possibility of simulating the interaction between sales, production, warehousing, and supplies of raw material. Even this difficult example of simulation is nearly a reality as well as process control through computer simulation in certain industries.

Simulation, and particularly computer simulation, has thus provided a means of solving classes of problems that were not feasible by previous techniques.

APPENDIX

Computer Simulation of an Inventory System

For purposes of reducing details it is assumed that there is only one item in inventory and that orders, placed on vendors, to replenish inventory require 30 days from the date of issuance to date of receipt. The inventory policy to be tested consists of two parts:

1. When to reorder.
2. How much to reorder.

The problem is to find the "best" inventory policy balancing the cost of inventory (which tends to require a low inven-

tory) with the cost of back orders (which tends to require a large inventory). The information required from the simulation could be:

A. What was the average size of inventory?
B. How many back orders occurred during the simulation period?
C. What was the cost of carrying inventory?
D. What was the cost of filling back orders?
E. What was the minimum, average, and maximum time a customer had to wait for a back order to be filled?
F. What was the cost of placing vendor orders?

As mentioned previously, the simulation should first be run using the actual inventory policy. Results of this simulation should be checked with actual reports of the real-life inventory conditions to check on the validity of the simulation program. When the simulation is satisfactory, various inventory policies can be tested by substituting different quantities (or methods) in the model for determining the order point and order quantity.

The input to the system could be actual orders from some historical period or else a statistical pattern of orders could be developed and random numbers used to determine orders. If the latter method is used the following information would be typical of that required:

Size of daily order	*Percentage*	*Cumulative percentage*
0	15	15
1	8	23
2	12	35
3	4	39
4	38	77
5	17	94
6	2	96
7	4	100
8 and above	0	100

In this case two-digit random numbers, 00 through 99, could be generated and compared to the Cumulative Percentage Table to determine order size by finding the first cumulative percentage that was larger than the random number. For example, the random number 32 is first exceeded by the cumulative percentage of 35, which in turn corresponds to an order size of 2.

The output required from the computer simulation to answer the questions posed above would be:

A. Total daily inventory.
B. Number of days' activity.
C. Number of back orders.
D. Total back order amount.
E. Maximum days waited for back order to be filled.
F. Minimum days waited for back order to be filled.
G. Total days waited for back orders to be filled.
H. Number of vendor orders placed.

These output requirements determine a number of steps that must be performed by the simulation. For example output G requires step 6 in the model and, in turn output G (total days waited for back orders to be filled) when divided by the total number of back orders will answer the question of the average time waited for a back order to be filled.

It is also a simple matter to alter the model to obtain additional information. The inclusion of step 3a in the model would answer the question of the maximum size the inventory attained which could be important in terms of space requirements.

In terms of the conditions stated, the model must provide for two information files maintaining activity by days:

1. Back order quantity.
2. On order quantity.

The back-order file will be loaded on waiting day 1 and unloaded from the highest waiting day. The on-order file will be loaded on days-before-receipt 30 and unloaded on days-before-receipt 1. The model could be made more elaborate by using probability patterns on the receipts (as on customer orders or using different priorities in filling back orders, but the following model gives the basic core of an inventory simulation.

Stepwise Representation of Inventory Model

Step	
1	Set calendar to 1
2	Is there a receipt? No—go to step 7, Yes—continue
3	Add receipt to inventory balance
3a	Check for maximum inventory quantity
4	Fill back orders from oldest waiting day
5	Check days waited on back orders filled for maximum and minimum days
6	Add days waited on back orders filled to total days waited
7	Is there an order? No—go to step 22, Yes—continue
8	Add 1 to number of orders
9	Add order quantity to total quantity ordered
10	Can order be filled? Yes—go to step 15, No—continue
11	Fill partial order
12	Put unfilled amount in back-order file
13	Add 1 to number of back orders
14	Add quantity back-ordered to total back-order quantity
15	Get new inventory balance
16	Is a receipt pending in next x days? No—go to step 18, Yes—continue
17	Is pending receipt sufficient to cover back orders? No—go to step 19, Yes—go to Step 22
18	Has re-order point been reached? No—go to step 22, Yes—continue
19	Compute order quantity
20	Put order quantity in on-order file
21	Add 1 to number of vendor orders
22	Step calendar by 1
23	Move on-order file forward one day
24	Move back-order file backward one day
25	Add inventory balance to total inventory balance
26	Test calendar for last day? No—go to step 2, Yes—continue
27	Output.

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The Institute of Management Sciences, Mount Royal and Guilford Avenues, Baltimore 2, Md.

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Presented at the 15th Engineering Conference of the Technical Association o fthe Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

Sixteenth
Engineering Conference
of the
Technical Association
of the
Pulp and Paper Industry

Shoreham Hotel
Washington, D. C.
Oct. 15–19, 1961

Recommendations for a Modern Finishing Room

RICHARD G. CARTER

In the past three years several types of new sheet finishing equipment has been developed. In most cases a new piece of equipment has been installed to solve a particular problem. If we are to fully utilize what is available, the entire finishing operation should be analyzed. Perhaps a whole new system should be developed. With the material handling devices and packaging equipment available, a continuous flow system can be practical to minimize the manual handling and packaging from cutter through packaging. Such a system has tremendous advantages in lower production costs with less manpower. It also has problems which need to be recognized and solved. With all equipment interdependent, quality paper to the finishing room is imperative. Beyond this we should be formulating future requirements for sheet finishing. This future step will require the cooperation and efforts of industrial engineers and supervisors, management, equipment manufacturers, paper salesmen and the customer. By analyzing and developing the overall finishing operation, costs will be reduced much faster than in the past.

PROBABLY no two of us would agree exactly on what comprises a modern finishing room. And yet, I think we can agree on some basic ideas and approaches to our mutual and similar problems. In the past three years, tremendous strides have been made in developing new types of auxiliary handling and packaging equipment for sheet finishing. But in most cases, these units have been thought of in terms of solving one specific, narrow problem in an operation. It's time for us to look at the whole finishing operation in light of what equipment and methods are available to us now, and in what future direction we should aim.

We have added equipment here and there to solve a specific problem, but maybe we should have eliminated the whole operation. To make real progress we must have an overall dynamic improvement plan in which each addition contributes to our goal. I would like to develop two types of layout this morning that will illustrate this concept: a continuous flow finishing operation with existing equipment, and a future finishing room that we should be developing as a future goal.

You may say these systems won't work in your operation, and maybe they won't. Then analyze your own operation completely and try to develop a system which will work. The examples I want to use are for sheeting coated printing papers, which are about as critical as any sheeted stock in quality and dimensional tolerances.

First of all we need to analyze thoroughly our entire finishing operation. Question each phase and take nothing for granted. Let's ask three questions concerning a typical finishing room sheeting printing papers.

1. Does each operation add value to the paper or does it merely move the paper from place to place?

2. Are we getting the most value from our inspection methods?

3. Do we have an overall improvement plan, so that each change can be evaluated on the basis of its contribution to our goals?

Now let's review them in more detail.

1. How many men are actually performing operations and how many merely move the paper from one place to another? To perform the three basic operations of cutting, trimming, and packaging, we handle the paper as many as eighteen times. If you produce 100 tons per day you will possibly move 1800 tons of paper, counting each individual time it is moved from a stationary position. Insofar as economically and physically possible, equipment should be moving this paper.

2. What is the effect on costs of all this fanning inspection? Granted we need to ensure our customers that they are getting the finest quality paper that can be provided. But, inspection merely removes some of the poor paper often at a cost disproportionate to the value. If we want to provide quality we must build it into our product from the start of our papermaking process. If we consider coated printing papers, most of the production is shipped in roll form. The sheet is inspected by the backtender as it is wound on the reel. Again it is inspected as the sheet is supercalendared. A relatively small amount of inspection is carried on at the rewinder, because of the speed. Both shipping rolls and sheet rolls receive the same inspection through these operations.

Rolls are apt to be run on printing jobs just as critical as sheets and at higher production rates. Mechanical defects are more serious in web presses with greater potential losses in production and paper. Plate damage would be equally serious on either type press. But which ton of paper gets more inspection time; the ton in roll form or sheet form?

In most finishing operations, the bulk of inspection is between the cutters and trimmers. Most of the defects detected are holes, calendar marks, streaks, dirt, splices, etc.; defects which are from previous operations and which have been inspected for in roll form. Defects from the cutter; turned under corners, shoe marks, and cutter wrinkles, can better be inspected for at the cutter by periodic checks while running. Defects from operating can then be corrected before running off several skids. This procedure has been effective at West Linn for over 5 years using only one girl for inspection ahead of the trimmers. This is an area where statistical quality control can also be effective. For maximum benefit, quality emphasis is required back through other operations to the stock furnish.

At the present time, automatic bump and void detection devices are available for use on paper machines and supercalendars. Complete success has not been experienced with these devices, but as they are perfected, effective inspection for these defects can be achieved for both rolls and sheets.

3. Most finishing rooms are layed out and operated like job shops. Like machines are grouped together and paper is stacked and stored and unstacked and handled from one operation to the next. Occasionally a new type of equipment is developed, and it is squeezed in and set in place. Over a period of time the finishing room grows without analyzing an overall plan of development or operation. To get the fullest potential from this new equipment we should not overlook the importance of devising new systems, and layouts to utilize them.

Let's review some of the developments in sheet finishing equipment and then evolve a system that will combine these into a unified layout.

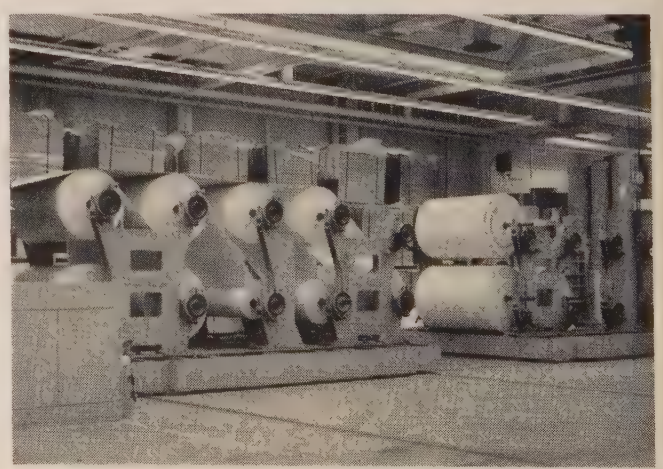

Fig. 1. Cutter dual backstands

RICHARD G. CARTER, Crown Zellerbach Corp., Camas, Wash.

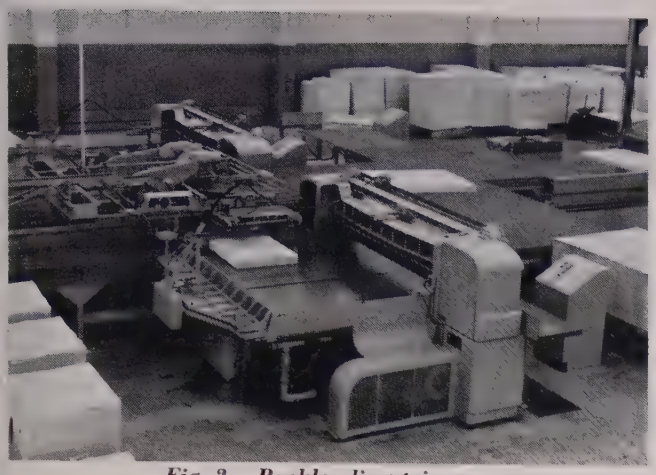

Fig. 2. Backloading trimmer

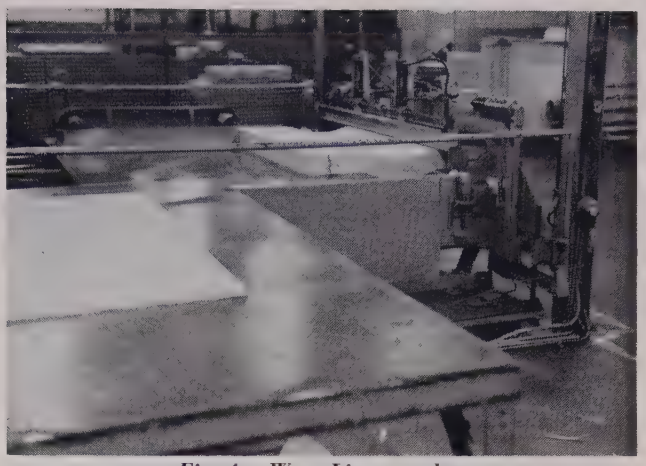

Fig. 4. West Linn stacker

CUTTERS

A conventional cutter for sheeting rolls may have up to 50% downtime. This results from loading a new set of rolls on the backstand, from removing skids of cut sheets, and from size changes and maintenance. These material handling operations of loading and unloading paper at a cutter can be substantially reduced with equipment now manufactured.

Dual backstands on a turntable or on two cars on L shaped tracks allow loading one backstand while the other is running. At the end of a set the empty backstand is moved aside, the full one run into position, and the webs are fed into the cutter.

On some grades and roll sets, up to 1 hr. per cut is lost in removing full skids from the cutter. The continuous layboy allows the cutter to continue running at production speed while sheets are removed either on a skid or on a conveyor. One type consists of two stations, with a gate diverting sheets to one or the other of the layboys. Sheets stack in one layboy while they are removed from the other. The other type consists of a set of fingers ejecting out to support the sheets while the pile or skid is lowered and removed, and the table or a skid is raised under the new pile. With this combination, a cutter should run 75 to 80% of the time depending on the number of size changes, maintenance, etc.

TRIMMERS

Basically the trimmer has not changed much, but many companies now backload behind the knife as seen in Fig. 2. This saves handling time by automatically loading the trimmer and by removing trimmed sheets at the same time. Several types of conveyers are used and do a good job. The conveyor shown consists of air tables with an overhead flight conveyor feeding to the trimmer. When the trimmer back fence fully retracts the sheets are automatically backloaded by an air operated flight. Other types are slot conveyors, belt conveyors, and a reciprocating flight which raises to allow stacks to pass beneath, then lowers to the table and pushes the stack onto the trimmer table.

PACKAGING

Most companies are employing some types of machines or aids to assist in packaging. The following are some Crown Zellerbach is using.

Skid Stacking

There are several types of fine stackers to choose from and each has its own advantages.

Figure 3 shows the new design at St. Francisville, where machine pits can be utilized. The St. Francisville unit consists of a hydraulic life supporting the skid. A tray which travels horizontally advances over the skid to a clamp. The stack is jogged against the fence, clamped at the leading edge, and the tray is withdrawn, leaving the sheets neatly stacked on the skid. After the tray withdraws, the hydraulic lift automatically lowers and is ready to receive the next stack. When a full skid is stacked the clamp assembly raises and the skid is ejected on a roll conveyor to the skid finishing area. A new skid with wrapper is fed into place on the lift, and with a slight alignment by the operator, stacking again starts. This unit will handle single or double stacks at up to four skids per hour. With proper layout one man can stack as much as eight men could by hand.

Figure 4 has been in operation at West Linn for over 5 years and is a design which does not require cutting into the

Fig. 3. St. Francisville stacker

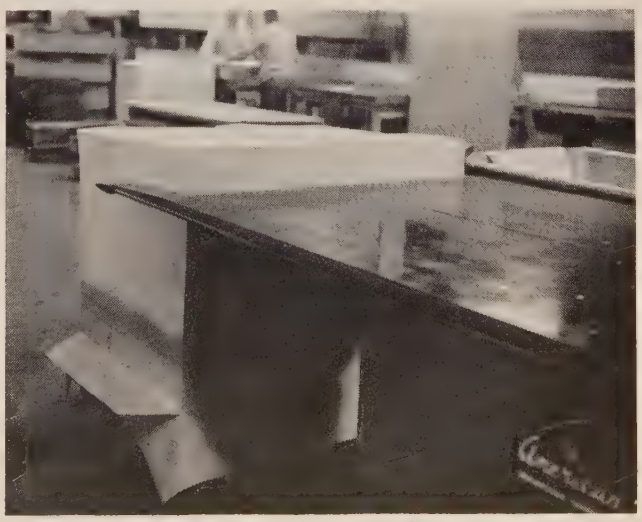

Fig. 5. Spear stacker

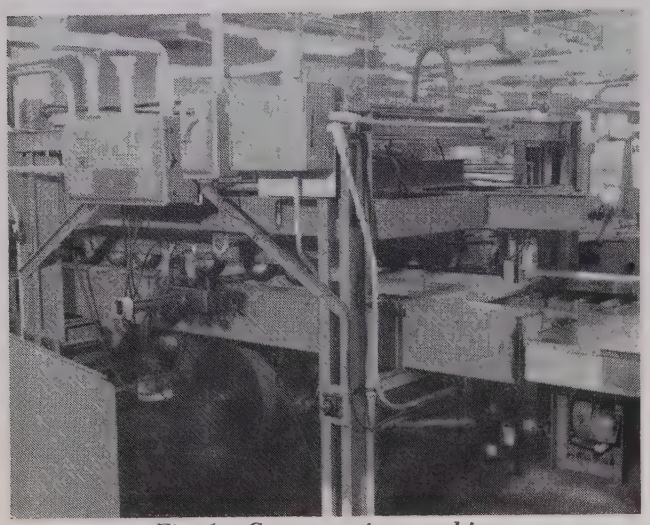

Fig. 6. Carton taping machine

floor. The skid is stationary while stacking, and the tray raises and lowers to the proper height before advancing over the skid to the clamp. It is effective, but not as fast as the unit with a hydraulic lift.

Two smaller skid stackers are available at much less cost; straddle stackers and cantilevered spear stackers (Fig. 5). Either of these can be operated with or without a built-in lift. Faster stacking is accomplished if a separate lift in the floor is used, which allows stacking at a uniform elevation. It is easier to control the paper and is less fatiguing for the operators.

With these units four stacks can be piled on a skid. The four stacks are slid onto the spear air table which advances over the skid. The first two stacks are aligned and butted against the backboard and held while the spear retracts beyond the first two stacks and stops. The last two stacks are then slid forward to butt against the previous stacks. They are held while the tray retracts, leaving a neatly stacked skid. These units operate faster with just single or double stacks. Similar units can also be used for breaking down cutter skid loads ahead of the trimmer.

Carton Taping

Conventionally, telescoping sheet cartons are hand taped peripherally on a turntable machine. Cartons are loaded by two men, the top put on and manually turned bottoms up. Two other men apply tape to the carton side, rotating the carton one revolution and folding the tape over the edge, sealing the bottom. The cartons are again turned over manually and stacked on a pallet. Labels and stencils are applied either before or after palletizing

Two relatively new carton sealing machines are now on the market, each with different type sealing. If the telescoping carton can be glued, a smaller, less expensive machine can be used. The carton is hand loaded, glue is applied by hand to the flaps, and the top section is placed over the bottom. The filled carton is shoved into the sealer. A sealing blanket lowers over the carton, and vacuum removes excess air and seals the carton. This machine will handle two cartons per minute of various sizes simultaneously without readjustment.

The other taping machine and system is used in both our West Linn, Ore., and St. Francisville, Louisiana Sheet Finishing Departments to peripherally tape telescoping gloss cartons.

Figure 6 is a two-stage taping machine which is capable of taping two cartons per minute of one size at a time. To change sizes requires about 15 min. We are using reinforced 4-in. tape stock and applying adhesive at the machine. On each section a lead screw change for each of length, width, and height is made, which changes all operations for that dimension on one section. The carton is moved through the taping section on powered rollers. Cartons are separated by 8 in. going through the machine by stops at each stage within a section. As a carton moves past the first stop, two 4-in. strips of tape are applied to the bottom, and the tape is folded up the side with pressure rolls. A series of inflated rubber hold-down rollers hold the top down for a tight package, and also take care of bulk variation. At the cutoff station a knife severs the tape, and a plow type folder folds the 4-in. strip of tape around the corners of the two cartons and holds it in place until the succeeding carton hits the first stop. After sealing the corners, the carton moves through a pressure station to a right angle transfer station. The carton then enters a duplicate second section for taping of the other two sides. Cartons from the second section feed to a palletizing station where one man can load them onto pallets, if a lift is provided.

LAYOUT

Obviously, finishing rooms differ in equipment, grades, and auxiliary operations. It would be impossible to devise one best system for all types of finishing. Therefore, it is the principles and philosophy applied to an operation that is important in developing it. To allow us to use an example let's define a finishing room that is to be layed out from the beginning. The only product will be printing papers, but of various grades, basis weights, and sizes. Packaging will primarily consist of skids and carton pack. If sufficient volume warrants the investment, a wrapping machine could be installed for ream wrap sheets. Production would range between 60 and 90 tons per day on a two shift basis.

To start with let us review a typical finishing room sheeting printing papers. Let's pinpoint the operations that can be eliminated, that can be combined, that can reduce labor and effort by mechanization, and that can improve machine utilization and reduce waste.

In this operation (Fig. 7) a cutter with single backstand requires the rolls to be loaded while the machine is stopped. Full skids are removed while the cutter is stopped and then are transported to an in-process storage area. The skid load is then transported from in-process storage to a loading and inspection station. Some finishing rooms require a separate move between inspection and loading to the trimmer. The paper is pulled from the skid manually into trimmer lifts. The sheets are fanned for inspection and perhaps checked for count. As required they are manually pushed into the trimmer on an air table. From the trimmer the sheets are shoved to the packaging station. Much packaging is still done manually for carton sealing and skid stacking, even though mechanical equipment is available to do an equal or better quality job with much less time and physical effort. Stacked skids are then moved to a finishing area for wrapping, strapping, and weighing. The packaged sheets are then moved again to finished storage to await shipping.

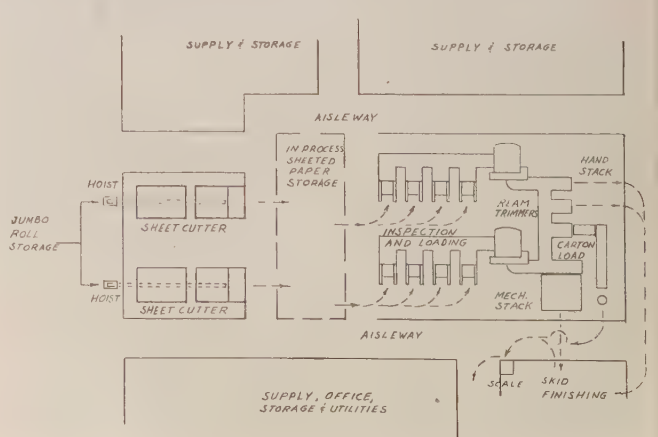

Fig. 7. Conventional sheet finishing

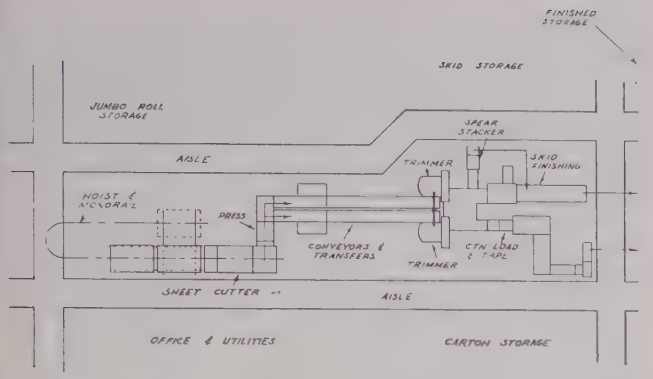

Fig. 8. Continuous sheet finishing

This essentially is a description of a conventional finishing room. I assume that most of your sheet finishing operations at one or more stages utilize some of the mechanization we have discussed.

Now let's again take a look at some of the questions we previously asked. A key question is: "What can we eliminate?" A major operation affecting the feasibility of other mechanization is the large amount of fanning inspection. The customer doesn't care how or where the paper is inspected, as long as he gets quality paper free of the defects that will cause trouble in his operation or will reduce quality of his finished product. Many progressive companies have found that inspection at other locations by other methods not only reduces labor, but is more effective. After all, inspection has a twofold purpose—to eliminate a defective production and also to indicate action to eliminate future defects of the type found. Most of the defects found in a finishing room are from previous operations, and should be detected and corrected in those operations. What good is it for corrective purposes to find out in a finishing room that the paper produced two or three weeks ago was defective? Defects from the cutter operation can be more quickly corrected if inspection sampling is carried on at the cutter as previously described.

If this type of inspection can be reduced between cutter and trimmer, it allows another step to be taken. Stacking paper skids at the cutter and unstacking at the trimmers requires extra time and manpower and also requires two scheduling operations instead of one. To stack sheets in trimmer lift heights at the cutter and transfer them directly to the trimmer would allow a continuous flow from roll form through the packaging operation. For some operations this is practical, and with others it is not due to product mix, due to existing buildings, or due to economics. With the packaging equipment described earlier, a complete production line system can be evolved to produce more economically.

Fig. 9. Distribution table to packaging

Fig. 10. Skid finishing line

Let us develop a continuous-flow sheet finishing operation using equipment that is now available from several manufacturers. Our objectives are to minimize manual material handling, which reduces labor requirements; to pace production through the department, which eliminates delays; to reduce waste; and to maintain quality and safety standards.

First, for a continuous system (Fig. 8) we must eliminate long delays at any point. At the cutter, these delays can be minimized by use of dual backstands and a continuous layboy delivery. Dual backstands will reduce time for changing roll sets to about 10 min. A continuous layboy would eliminate all time now spent in removing full skids. The only other down time would be for size changes and maintenance.

The cutter can discharge stacks of paper from 4 to 7 in. high without stopping, and the trimmers can be automatically backloaded. If these two units are connected by conveyor, the manhandling of paper between the two operations can be eliminated. As sheets are conveyed out of the layboy, they are pressed to remove air entrapped between the sheets. This makes conveying stacks more stable of the air table. Air tables with overhead flight conveyors transfer the lifts to the trimmers. Two conveyors to each trimmer are used to allow the cutter and trimmers to operated completely independent of each other within the storage capacity of the conveyors. Inspection air tables can be provided for each conveyor to allow occasional inspection between operations.

Two trimmers are used to allow better utilization of the cutter and the capacity of the packaging equipment. After trimming, the sheets are either skid packed or cartoned. In this layout a mechanical stacker, a spear, or straddle stacker and a carton taping system are required. They are layed out so that production can be diverted to any line from the trimmers without delay and without moving equipment in or out when used. Therefore, a common distribution air table between the two trimmers and three packaging lines allows a minimum of handling and change-over time. With this system a three or four man packaging crew would switch to different packaging lines as the schedule indicates (Fig. 9).

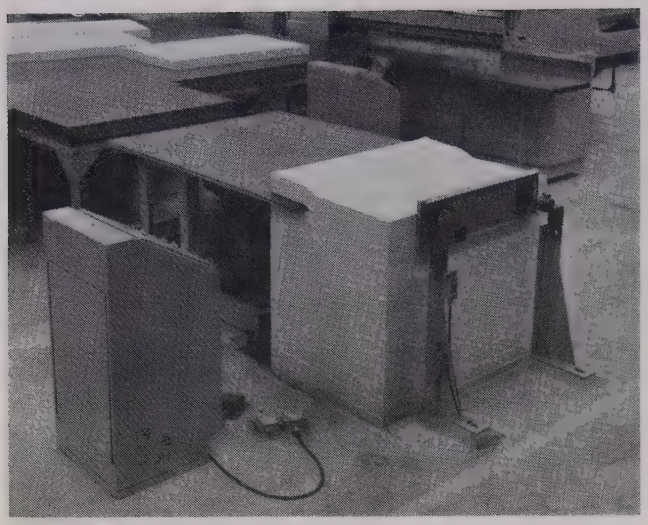

Fig. 11. Spear stacking lift and backboard

Fig. 12. Carton loading tables

The main stacker would be used for single or double tiered skids which comprise about 80% of skid production. To facilitate production on the skid packing line, a skid finishing conveyor system can be incorporated (Fig. 10). Full skids would travel out of the stacker onto the conveyor and an empty skid would be conveyed onto the lift, ready for alignment by the operator. One man operates the stacker and two men wrap, strap, label, stencil, and weigh the loaded skids. The scales are on one section of the conveyor. An overhead hoist is used to facilitate strapping by supporting the strap and strapping tool. For greater production a fourth man can be used.

The spear or straddle stacker (Fig. 11) will be operated by two men to stack four tier skids which comprise the remaining 20% of skid production. A stationary backboard is used to align the sheets. The skid will lower on a hydraulic lift as sheets are stacked at a uniform elevation. Full skids are transported to the skid finishing conveyer system where two men wrap the skid.

Telescoping corrugated cartons are loaded by two men (Fig. 12). Paper is slid from a cantilevered air table into a flat carton bottom, which is sitting on a table extending under the cantilevered section. The sheets are aligned with the carton sides, and to load, both paper and carton bottom are pulled toward the taping machine. The table ahead of the taping machine has a built-in hydraulic lift to allow the carton to be loaded in two steps by the same process. The bottom is left unstitched and the sides are folded up as the stitched top is placed over the carton.

A filled carton is shoved into the infeed conveyor (Fig. 13) of the peripheral taping machine for automatic taping.

From the machine's conveyor discharge one man palletizes, stencils, and labels the cartons. A hydraulic lift maintains a uniform elevation for stacking cartons, and a shuttle table with roller top allows positioning the carton on the lift without lifting. A filled pallet is rolled off the lift onto a conveyor section for transfer to a finished storage area. In this way production is not delayed while a truck unloads the lift.

Naturally, this continuous flow system would create different operating procedures and problems than the conventional system.

1. The equipment will not always run at maximum speed, but will run at the optimum speed depending on sheet size, order size, roll set size, type of packaging, trimmer capacity, etc. The net effect is reduced operating costs with a minimum of operations and handling. If two or three rolls per set are run on the cutter, a speed of 600 to 700 f.p.m. may be necessary to operate subsequent equipment to potential. For this reason the system may not be adaptable to older cutters incapable of this speed.

2. A millwright should be available at all times. If a breakdown occurs in the system, the whole line goes down in a short time. Preventive maintenance would be essential. Whenever operations are mechanized, maintenance costs usually increase, but the increased productivity justifies these costs.

3. With this system, the cutter is scheduled and the trimmers and packaging operations must handle it. Of course, the cutter must be scheduled within the limitations of succeeding equipment. Supervision will have to expedite the system to be sure all supplies are on hand at the proper time to avoid delays.

With this system, production is best thought of in terms of trimmer lifts cut per hour. Tonnage will vary considerably with sheet size, grade, basis weight, number of cuts made on the trimmer, etc. However, a relatively uniform number of units can be processed through the respective machines. Management, supervision, scheduling personnel, and employees will need to adjust their philosophy to think in these terms.

4. Production rates will be increased because the whole operation can be paced. Then the cutter runs at a given speed, the trimmers will have paper to be trimmed and the packaging operation will have paper to be skid packed or cartoned. Actually the cutter should run faster than the trimmers to fill the conveyor before running out a set. This will allow the roll and size changes to be made without long delays in trimming and packaging. A short break between sets will allow personal time.

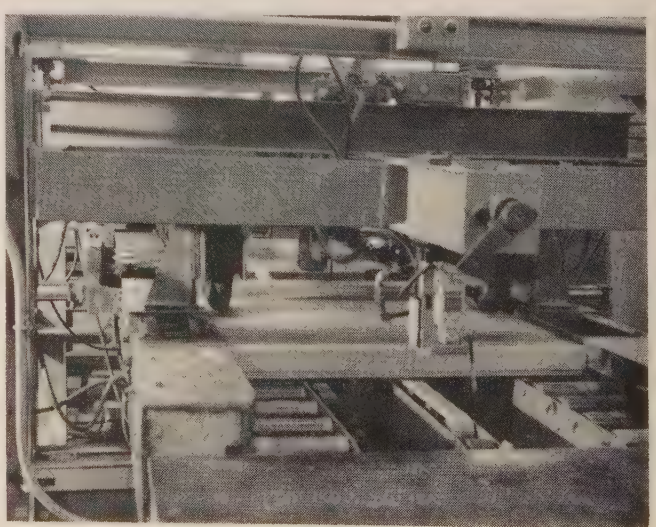

Fig. 13. Carton taper infeed

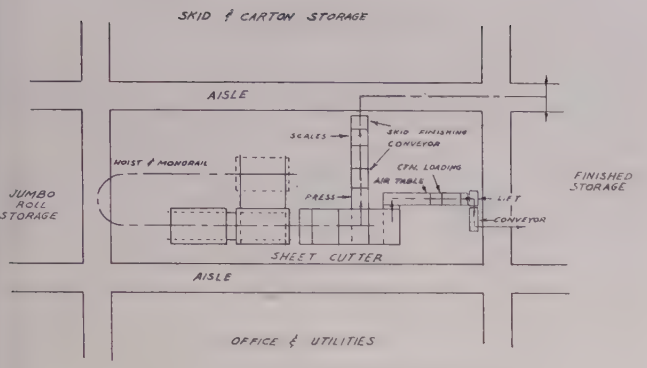

Fig. 14. Future sheet finishing

5. With this system, good paper quality to the department is essential. Individual sheet inspection or widespread fanning inspection is impractical. Quality has to be built into the paper before it gets here. For a minimum of waste, this is essential in any system.

The foregoing is what I feel is practical with existing equipment and within standards of what the industry will accept. This system is far from an ultimate system. For a few minutes I would like to discuss a few items that we should consider as engineers, suppliers, converters, and as customers for future improvement. Some of these require a welding of all these interests to accomplish them.

1. We should try to make a cutter accurate enough to allow the elimination of secondary trimming, except for splitting sheets into smaller ones. For many grades, this is already accomplished, but for printing grades, trimming is generally required to assure accurate dimensions and squareness for color register. Think of the labor and equipment reduction in rehandling and trimming. This will require different design principles, perhaps different materials to maintain the accuracy, but someday we should expect this accuracy. A much higher degree of accuracy is achieved in other industries and should be possible with paper cutters. Packaging could be achieved in a continuous flow from the cutter. Perhaps 75 to 80% would be skid packed, and this could be done on the layboy directly to a shipping skid or pallet. If accurate jogging cannot be accomplished on the layboy, the skid could be moved on a conveyor to a vibrating platform which tilts to jog to a corner. With two adjacent sides accurately cut and stacked, printers should be able to achieve accurate printing register. The customer's cooperation and acceptance of these methods would be essential for success.

2. Telescoping cartons with pressure sensitive glue applied by the manufacturer would eliminate the need for expensive closing equipment, space, and manpower. With the acceptance of glue closure replacing peripheral taping by customers, this method would be feasible. However, there are problems of storage to avoid them contacting and sealing with other cartons. Dust and aging also have an effect on the sealing properties.

3. The use of disposable pallets in place of expensive skids would save customers thousands of dollars annually. Most finishing rooms can handle pallets as easily as skids, but the small printers using platform trucks will not allow complete change-over to pallets. If pallets were actively promoted by the paper companies, a gradual change could take place as platform trucks are replaced in the customers' plants.

4. Standardizing sheet sizes would result in longer production runs, with the attendant benefits of less downtime, waste and delays, and a reduction in cost. Any list of sheet sizes shows a few standard sizes, with other at $^1/_4$-in. intervals. In many cases, a standard size could be used for a particular job if the customer was given a choice of sizes or asked to change to a standard size. To accomplish this objective would probably require either a discount on the standard sizes or a penalty on the nonstandard sizes, coupled with an informal educational program to salesmen, jobbers, printers, and customers. To whatever degree size standardization could be accomplished an attendant cost reduction would follow.

To these you can add your own pet ideas to what changes are required for a future modern finishing room. For a finishing room of the future comparable to the two previous layouts we might have something like this (Fig. 14).

For operating such a department about six men per shift would be required, plus supply men and supervision. Dual backstands and a continuous layboy would keep running time at a high level. Shipping pallets would be stacked on the layboy and conveyed out the side to a pallet finishing conveyer system similar to the one previously described for skids. Sheets for carton loading would be conveyed out the other delivery in carton height quantities to a carton loading station as previously described. The carton top would seal with pressure sensitive glue as it is placed over the bottom section. Palletizing the finished cartons would be by the same two packaging men onto a hydraulic lift. Finished pallet loads would roll to one side for transfer to storage.

If sheet finishing operations are to keep pace in this era several things must happen.

1. Industrial engineers and supervision must project production and equipment needs into the future. We must indicate to equipment manufacturers the needs of our industry and cooperate in the development of equipment that will fit an overall system. We must go farther than the customary single problem solving stage in which most of us find ourselves.

2. Management must allow and promote an atmosphere in which this development can take place. In the development of new equipment, a reasonable time must be allowed to shake down the machine or a complete system. Unfortunately, all the problems are not foreseen before the construction stage. New concepts and philosophy of production must evolve with a new system, and these ideas must blend in with supporting departments and services.

3. Equipment manufacturers must work very closely with mill personnel in the development of this new equipment. As they observe operations in various companies they can see common problems which can be solved by suggesting different approaches. It seems to me that it is the responsibility of equipment manufacturers to translate these potential future needs of the mills into practical machinery. Our paper companies are spending millions of dollars on basic research in the hopes of developing a marketable product or a means of reducing the stream and air pollution problems. I don't think it is unreasonable to expect equipment manufacturers to spend more research and development money to bring about the advancements required by the finishing industry. Such developments as a cutter that is accurate enough to eliminate subsequent trimming and rehandling would obsolete many of the existing finishing rooms. It would create new demands for this equipment.

4. Paper salesmen would be an important link to the customer in explaining changes and the advantages in cost and quality. Of course, he would also be important in this two-way communication in bringing to light customer problems as they might affect a proposed change.

5. The printer, or comparable customer, needs to understand the reasons for changes if they affect the product as he receives it. By cooperating in trials and meeting proposed changes with an open mind, improvements can be made, which will reduce costs and allow our finishing operations to be more competitive.

There is no simple one sure method of modernizing finishing rooms for cost reduction, but by some of these approaches and through increased cooperation of these groups we will progress faster than we have in the past.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

Electrical System Maintenance

F. J. HRABAK

Good maintenance requires a thorough knowledge of the drive equipment, and adequate stock of replacement parts, and qualified maintenance personnel—or, more simply stated, planning, parts and people. With the advent of more sophisticated control systems, greater maintenance problems are created if a workable maintenance program is not followed. Rotating equipment maintenance, short-cuts in trouble-shooting electronic control, spare parts stock assistance and training of personnel are discussed from a practical, work-aday viewpoint. Danger points are recognized, and advice is given as to sources of assistance in inaugurating and implementing a sound, over-all maintenance program for drives.

Today's continuous process industries, withir the sophisticated control, have amplified problems in the area of maintenance. With today's requirements of high-speed production, short delivery cycles, and emphasis on quality, elementary economic factors dictate that these machines be operated at maximum capacity on a continuous basis, in order to insure profitable operation. It's true that control is becoming more complex, but the factors affecting maintenance haven't changed a great deal. So let's take a common sense approach to maintenance; so that maximum use and minimum downtime are obtained from present and future equipment.

The factors involved are easy to visualize, and the steps to be taken are small, so let's look at *planning, parts, and people.*

COMMON SENSE PREVENTIVE MAINTENANCE STEPS

Planned preventive maintenance is not an esoteric crystal ball activity, but an application of common sense. Your plant is unique and the program you follow should be tailored to your needs. However, the basic procedures are common to all users of motors, generators, and associated controls. No special extraordinary care is necessary to keep your equipment in continuous and efficient operation; just proper and planned attention.

Step one in any preventive maintenance program is to plan and enforce regular inspection schedules. Your check list for periodic inspection and what to look for would include the following:

Brushes and Commutators

Check for sparking or arcing at brushes—as possible indication of overload. Note color and surface condition of commutator for cleanliness, checking for high bars, high mica, or roughness. All brushes should be inspected for wear, fit and free movement in brushholders, brush spring pressure, and loose connections.

On commutators of d.c. motors and on slip rings of wound rotor motors, dust acts as an abrasive and increases wear. As an insulator it may also limit the free passage of current. Dust accumulated on the winding of the motor, acts as a layer of insulation, restricting the heat dissipation and raising the operating temperature of the motor. With dust filling the open spaces in the windings, ventilation, and cooling of the motor is reduced and temperatures may reach dangerous limits. Dust and dirt, of course, will cause failure in bearings.

The commutator face should be clean, smooth, and have a medium polish. The surface under the brushes should have a stable copper oxide-carbon color, but not bright copper; the color of the film may vary from copper to chocolate. A proper film will automatically be maintained if the proper brushes are used, according to load and atmospheric conditions.

Do not "stone" the commutator of d.c. machinery: this is a job for the expert. Use a pad of canvas or similar hand-woven, nonlinting material occasionally to clean and polish the commutator. Never use grease or lubricant on a commutator. A mildly rough commutator may be ground and polished with commutator resurfacing or dressing stones, with the d.c. machine running at no load or being driven at its normal speed. If preferred, you can use sandpaper on a block of wood having the same curvature as the commutator. Never use emery or carborundum.

An extremely rough, out-of-round commutator should be turned in a lathe, taking very light cuts. The lathe speed should be at least as fast as the normal operating speed of the d.c. machine. After turning, grinding, or polishing, the commutator should be concentric within certain limits:

1. For peripheral speeds of 9000 f.p.m or over, the total dial indicator reading should not be over 0.0005.
2. For peripheral speeds between 5000 and 9000 f.p.m., the total indicator reading should be 0.001 or less.
3. An abrupt change from bar to bar of more than 0.0001. and a change of 0.00025 in less than one-quarter of the circumference, cannot be tolerated.

The correct undercut of the commutator mica segments is between $^1/_{16}$ and $^1/_{32}$ in. deep. The undercutting should be done with a cutter or tool about 0.005 wider than the mica.

Most commutator running face conditions fall into one of three groups. The only exceptions to these three general categories would occur if the armature had developed a short, were misconnected, or had an unstable commutator. The three conditions are:

1. *Threading.* Threading is the term used to describe the grooved lines that are found cut in the face of the commutator by bits of copper being transferred from the commutator to the brush; the copper makes the brush a cutting tool. In a clean atmosphere with the machine running at light loads, the copper is not burned or vaporized from the brush face, and therefore collects. To prevent threading, it may be necessary to increase the current density by: (a) removing some of the brushes, leaving an equal number of positive and negative brushes in the same face track; (b) increasing brush pressure, which accelerates brush wear and removes copper from the brush face, and (c) by replacing brushes with new ones having a different material composition, and resulting in a lower current density.
2. *Grooving.* Grooving is a mechanical condition caused by the abrasive material inherent to carbon brushes. Grooving can be eliminated by using carbon brushes that have a minimum of abrasive material at recommended brush tension.
3. *Bar Marking.* Bar marking is the discoloration or etching of the trailing edge of the commutator bar. This condition results from arcing between the brush and the commutator segments. There are two kinds of bar marking:

(a) Slot bar marking, which is related to the actual winding configuration in the armature; that is, related to the number of conductors per slot. Slot bar marking becomes more severe with poor electrical adjustment or increased load on the machine.

(b) Pitch bar marking, which produces low or burned spots on the commutator surface. The number of these markings usually equals half the number of poles on the machine; after running long enough the commutator markings may equal the total number of poles.

In slot bar marking, either the load is too great for the machine, or the machine is greatly out of electrical adjustment. It cannot be completely eliminated, but can be controlled by: (a) maint ainingproper loads, (b) maintaining proper electrical adjustment, (c) controlling atmospheric conditions, (d) using proper grade and type of carbon brushes.

Pitch bar marking is caused by some cyclic action which occurs with every revolution of the machine. The cyclic

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condition could be unit vibration, armature unbalance, defective bearings, or unit misalignment. In many cases, the marking can be controlled by increasing the brush pressure.

Before deciding to change the grade or type of brushes, be sure to consider some of the other factors which could cause poor commutation.

Ordinarily, when we see sparking at the brushes, our first reaction is to change them. But the sparking could be caused by load, atmospheric conditions, operating practices, service conditions, machine adjustment, or any of a number of mechanical or electrical faults. Only after you have checked out these other variables and determined that the primary cause of the sparking is in the brushes, should you consider a change in brush grade.

It's impossible to lay down a fixed rule for selecting the correct brush grade to remedy any one specific problem. You have to take measurements, gather facts, and analyze them in the light of previous brush experience in the mill or plant before making an intelligent choice.

Lampblack base electrographitic, nonabrasive brushes are commonly used in grades SA-25, SA-35, SA-45, and SA-50. As the grade number goes up, the commutation factor improves. In other words, you get better commutation ability and higher current density capacity, but the brush life shortens. Because of the manufacturing methods, these electrographite-type brushes have a higher thermal conductivity than other types, and can be operated at higher commutator speeds, under heavy loads, on applications where no serious atmospheric contamination exists. The brushes should operate under a pressure of 2 or 3 lb. per sq. in. of brush contact with the commutator face. For d.c. machines where load in amperes is known, the current density can be calculated by using the formula:

$$CD = \frac{I}{1/2N \times W \times T}$$

where

CD = current density in amperes per square inch
I = load on machine in amperes
N = total number of brushes on machine
W = width of brush in inches
T = thickness of brush in inches

Brush grades SA-25 and SA-35 are generally used on machine applications where the commutator surface speed is less than 5500 f.p.m. Grade SA-45 and SA-50 are designed for higher seeds up to 8500 f.p.m., where a brush grade with a higher commutation factor is needed.
Peripheral speed is calculated by using the formula:

$$PS = \frac{3.1416 \times D \times N}{12}$$

where

PS = peripheral speed in feet per minute
D = diameter of commutator in inches
N = speed of commutator in revolutions per minute

Once you have information on the current density, peripheral speed, atmospheric conditions and the other factors we've mentioned, you can choose the correct brush grade for the job. From the physical standpoint, brushes are interchangeable in size, regardless of grade. In judging brushes, remember that the electrical characteristics are the most important factors to good brush performance.

Other than the standard nonabrasive grade we've mentioned, brushes come in grades that vary in degree of polishing action, and also in types according to degree of abrasiveness. Abrasiveness is the mechanical grinding and polishing action a brush exerts on the commutator. Abrasiveness should never be confused with hardness. They are distinctly different and do not bear any direct relationship to each other. Hardness is the relative resilience of the brush material, as accurately measured by an instrument.

Merely changing brushes from one grade to another is not always the final answer to good commutation performance; the new brushes may even perform worse than the old ones. In many cases, it may be necessary to readjust the neutral rocker position and to change the interpole strength by changing the air gap.

Bearings

Check bearings for signs of noise, vibration, heating, proper lubrication. It should be emphasized that more failures occur from excessive greasing than under greasing. Too much grease packed in the bearing cavity results in churning, excessive heat, and deterioration of the grease.

Four main types of bearings are used in motors and generators:

1. Cylindrical roller bearings
2. Single-row double-shielded ball bearings
3. Spherical roller bearings
4. Sleeve bearings

Bearing manufacturers claim that 90% of all bearing failures are caused by dirt. The remaining 10% are caused by improper lubrication, misapplication, and misalignment. Even the shipping of motors or generators without properly blocking the bearings can cause premature failure.

The selection of bearings by the motor or generator manufacturer is made on the basis of load, application, speed, and temperature. If it necessary to replace bearings, the new bearings should be identical to the ones originally supplied by the manufacturer.

Lubrication is most important to proper bearing performance. In general, it is best to accept the motor manufacturer's recommendation on the type of lubricant to be used. Perhaps we should take a moment here to discuss just what a grease lubricant is.

Grease is oil held in a jelling agent, usually a soap. The oil is the lubricant and the soap base is used to hold the oil near the bearing in much the same way that a sponge holds water. Additives in the various types of grease give it other properties for particular applications.

Some bases are usually a combination of metals and fatty acids, such as calcium (lime), sodium (soda), aluminum, barium, lithium, and strontium. The fibrous structure of the soap gives it its "sponge" effect. About 20 to 70% of the weight of grease is soap; the remainder is oil.

Other bases are available for special applications, but they have limitations. For stability over wide temperature ranges, a silicone lubricant is used. However, at lower temperatures, it has a tendency to "squeal" and will wear parts and bearings quicker than ordinary greases. It is a matter of engineering know-how to be able to select the exact type of grease for each type of bearing.

In grease-type bearings, use a grease that is neutral and nonfibrous, with a melting point of 350°F. The grease should have a very slow oxidation rate, with a minimum tendency to separate into oil and soap. In general, the lubricant used should have a melting point of at least 100°F. higher than operating temperature.

In sleeve bearings, use a good grade of lubricating oil of high chemical stability and in the viscosity range from 200 to 350 Saybolt at 100°F. Normal sleeve bearing operating temperatures are between 130 to 140°F., or about 60°C. total rise including room ambient. Sleeve bearing temperature relays are normally set to open the circuit between 165 and 170°F., or 77°C. Should the room ambient be high, the maximum setting should be 180°F., or 82°C.

In ball and cylindrical roller bearings, the bearing temperature should be checked frequently. If it is excessive, investigate the cause immediately. Normally, bearing temperatures should not exceed 50°C. (122°F.) rise above room ambient. Causes of high temperatures are: (1) contamination of grease, (2) too much or too little grease, (3) wrong

grease, (4) excessive load or thrust due to misalignment or unit overload, (5) loose or cocked bearings, (6) actual fatigue of bearings (7) excessive ambient temperature.

The frequency of lubricating the bearings depends upon such factors as speed, temperature, size of bearing, load, type of bearing, and the location of the machine. High ambient temperature will necessitate more frequent greasing. Units subjected to water splashing, high humidity, or the elements, should be greased frequently to freshen the old grease and drive out any water that might be present.

In general, equipment operating at temperatures of 0 to 50°C. under normal plant conditions at speed of 3600 r.p.m. and under, need be greased only three or four times a year. This based on normal operation of 8 to 16 hr. a day. Large three- and four-bearing power unit sets equipped with ball bearings and operating at 1800 r.p.m. and slower, require lubrication about three or four times a year. Motors or generators with cylindrical roller bearings should be greased at least four or five times a year. Bearings of size 315 and larger, operating at speeds above 1800 r.p.m. with grease temperature of 80 to 90°C., need relubrication at more frequent intervals; a small amount of grease should be added after every 700 hr. of operation. Extremely high-temperature, class H motors operating in high ambients should have heat-stabilized bearings lubricated with silicone greases.

Windings and Insulation

Check for cleanliness, clogged ventilating openings, evidence of moisture, or accumulated oil or grease. Insulation resistance measurements should be made and recorded with note of any trend toward failure to ground.

The insulation system is generally considered to be the weakest link in the proper operation of most types of electrical equipment. Moisture, heat, dust, dirt, oil, corrosive materials, and deterioration are all enemies of good insulation. If they are ignored, the insulation weakens and is that much closer to failure.

Every industrial user of electrical equipment should make periodical tests of insulation resistance, and record them on a card. If the tests indicate that the insulation is consistently growing poorer, the equipment should be removed from service before the condition becomes dangerous. When dealing with machines that are rated at less than 1000 kva., the accepted approach is to use the time-honored formula of 1 megohm per 1000 v., with a minimum of 1 megohm:

$$\text{Insulation resistance (in megohms)} = \frac{\text{Rated voltage} + 1000}{1000}$$

Keep in mind that the insulation of a motor or generator is all that separates the electrical conductors from the mechanical assembly. Regardless of the class of insulation used, the insulation materials are nonconductors only when clean and dry.

Dirt and dust can be effectively removed with compressed air at about 50 lb. pressure. If the accumulation of dirt contains oil or grease, use a noncorrosive solvent to remove it.

If needed, apply varnish after the insulation has been thoroughly cleaned and dried out. Two dips and bakes may be sufficient for normal conditions. For extreme conditions of moisture and corrosive atmospheres, four dips and bakes may be justified. The varnish supplier can recommend the temperature and duration of the baking required for the type of varnish you use. Make sure that you use a suitable temperature control, so you don't injure the insulation.

Insulation failure is seldom an immediate breakdown when some critical temperature is reached. More often, thermal aging makes insulation vulnerable to failure from a number of causes. Among these are: (1) expansion and contraction stresses from relative movement of windings, (2) mechanical vibration and shock, (3) moisture and contaminated air, (4) electrical stresses.

Insulation failures due to overloads or high ambients depend on the actual condition of the insulation and its rating. You can operate at a higher-than-rated temperature, but it cuts down on the life of the insulation system. Insulation life is cut in half for each 10°C. rise in temperature, whether it be due to operating temperature or a rise in ambient.

Surrounding Conditions and Mechanical Inspection

Check for excessive moisture splashing of water, leaking steam joints, etc. Check for proper ventilation—all power units with dust removing filters should have the filters cleaned and replaced regularly. Check for unusual noise—which may indicate misalignment of couplings, bearing failure, or internal mechanical defects.

Contactor Tips

Check movable parts for wear, check current carrying contactor tips for pitting and wear—replace when required. Check for loose connections at terminals, etc. Keep controls clean.

Electronic Tubes

Have tubes tested regularly with regular replacement program. The best way to handle tube replacements is to use premium quality tubes that have been aged a week in normal operation before putting them in equipment requiring the utmost in reliability.

The failure rate of brand-new electron tubes can hit 6% in the first 200 hr. of operation. After "sudden death" failures have been eliminated by preliminary burn-in, the failure rate will stay its lowest for the next 5,000 to 30,000 hr. of operation (depending upon tube type and design usage level).

As you can see, there is a statistical reason for blanket replacement of all electronic tubes at regular intervals. The exact point in hours of operation to make the replacement is determined partially by your mode of operation, and by the kind of equipment you are maintaining. Tube life is dependent on usage level from a design standpoint, as well as the ambient temperature. Tubes that are worked harder, from a design standpoint, will not last as long as those "loafing" in their sockets. The optimum replacement point in your plant will require record-keeping of failures versus time. Remember that with downtime costs mounting every year, you can buy a lot of tubes with the money you didn't spend for trouble-shooting and repair.

SPARE PARTS

Recommended spare parts for your plant will vary with many conditions, such as the location of the plant with respect to the sources of replacement parts, number of machines in operation, and the degree of importance placed on continuous operation. Here again, your record-keeping will be of great help in determining your stocks. Contact the suppliers of the equipment in your plant for specific suggestions and help in making sure you have the parts insurance you need. They may have a broader picture of your problem that can be of help to you and they will be most interested in keeping *you*, the customer, happy. Check with the service shops and distributors in your area. Many of them are willing to stock parts just for you, if they can be sure of getting additional business from you.

PEOPLE

It's quite obvious that the repair of any device hinges upon how well the trouble-shooter understands the equipment. When equipment and control is primarily nechanical, it takes about 10% of the time to analyze the trouble and about 90% of the time to fix the trouble. When electronic equipment is involved, the percentages reverse. The total time involved does not necessarily increase, but the time is now heavily dependent on the "know-how" of the maintenance man. Now, more than ever, a conceptual and functional knowledge must be obtained by maintenance personnel to do

a fast, efficient repair at minimum cost for downtime. Since the actual electronic repair takes a very few minutes after the trouble is found, the emphasis must now be placed on obtaining qualified persons to do the maintenance job. If you're lucky, you hire the man. Otherwise, you have to train him. If your company is large enough to have a training department competent to do the training job, you have no problem, but if your company can't help in the training area, what is you next step? The man you hire must have a wider background then was necessary 20 years ago. The electrical maintenance men now have to have an electrical understanding of the machine as well as a mechanical understanding, because no matter what happens in a machine that has electronic or electrical control, the electrician is called. If it's not electrical trouble, he has to prove it to the millwrights. The man on your maintenance crew, to handle the complex control, has to have background in at least the following: Physics, match, electricity, electronics, mechanics, theory of instrumentation, and motor and generator theory. In addition to these, he should have the ability to trouble-shoot systematically. Since you look elsewhere for help in developing potential material. If your plant can't help train your man, you can look to these sources for assistance:

1. Local colleges—Very often the local college has non-degree courses (technical institute type) which can be used to round out your new man.
2. Local high schools—More and more high schools are developing adult education courses at a very modest fee to satisfy industry requirements.
3. Correspondence courses—Where your plant has in operation a tuition refund program, this alternative can be attractive to the company and the employee.
4. Supplier schools—With the increase in complexity of industrial control, at least a score of companies have found high user acceptance for a school staffed by permanent instructors to provide fast exposure to the specific equipment to be maintained. To use our school at Reliance as an example, there is no charge for tuition or materials used in the 5-day school conducted at the main plant in Cleveland, Ohio. The school is conducted one week out of each month. There is no sales "pitch" involved, since the instructors are not salesmen and the equipment has already been sold. The course content should be mentioned so that the underlying philosophy of the school is understood. You would find in our course outline that most of the time is spent on the fundamentals of electricity, motors, generators, and electronics which applies to any company's products in allied fields. It is necessary to concentrate on the fundamentals, because it is almost impossible to do a good job of repair on trouble-shooting without it. All of us wish that a cut-and-dried procedure could be developed, so that no thinking would be necessary when shooting trouble. Unfortunately, there is no substitute for understanding how and why a device or machine works in order to make downtime small and productivity high.

When a customer finds that he has many men to train, it becomes economically unfeasible to send them all to Cleveland. To handle this problem, the school will go to the customer's palnt on a paid per diem basis for the length of time, and for as many men, as the customer chooses. We have conducted field schools in paper mills from Canada to Louisiana, from east coast to the west coast, for anywhere from 2 hr. to 2 weeks. This kind of help from your supplier can give you quick-to-the-point information on your equipment with short-cuts that might take your men many years to develop on their own.

TRENDS IN INDUSTRY TO INCREASE MAINTAINABILITY

With the missile era upon us, one of the facets of design to gain the spot-light is reliability. On a missile, *maintainability* isn't as necessary as *reliability*, since the equipment has to work only long enough to get into orbit or explode itself. Industrial control is a different breed of cat. It has to be reliable over long periods of time, and when it does fail, it has to be fixed "right now."

A more mature thinking pattern is developing, since there is a growing awareness that all equipment will fail sometime, and the problem is then that of fast repair. More emphasis is being placed on trouble-shooting information in the instruction manuals. Auxiliary test equipment can be plugged in to pin point defective parts or sections. Parts with high failure rate or limited life are mounted in sockets, so that soldering and unsoldering is unnecessary. Electron tube manufacturers are aware that the industrial market requires a better product than those used in T.V. applications. Since the industrial market for tubes is growing into a large percentage of the tube business, it is now sensible to spend development dollars to improve the breed. One of the problems that faced gas tube users was a way to predict tube life. Gas tubes have the characteristic of working well right up to where they fail completely. Reliance developed a gas tube that changes color when it nears the end of its useful life. To prolong life of electronic components under adverse ambient and environmental conditions, our company and others "pot" critical components in a protective material to keep out moisture, contaminants, insects, and people.

You, the user and purchaser of control equipment, are in the position of determining how much maintainability you wish built into the equipment you buy. Equipment is available incorporating "redundant" circuits to automatically by-pass defective sections. It wouldn't be here today if you the customer hadn't asked for it.

CONCLUSION

As we have stated earlier in the paper, there is no substitute for the properly trained maintenance man. In other words, you need a man with knowledge. He can get it from various sources: school, work experience, suppliers' training courses. But the important fact is that he must possess this "know-how," or any maintenance program is automatically doomed to failure.

Certainly, accurate records are essential to any good program. It's possible to plot probability of failure of certain components, merely by carefully analyzing your performance records. This will also tell you what number and type of parts to keep in stock.

Work with your plant management in scheduling regular maintenance "downs" in which you can go over the electrical equipment . . .and make such downs at intervals based on your records of probability of failure. If other departments are going to be down for one reason or another, be sure to communicate with them in an attempt to do the entire maintenance job in one back-breaking swoop. Working with your plant management will help to bring about these improved communications that will help you instigate a good *preventive* maintenance program that will reduce or altogether eliminate downtime due to equipment failure.

I repeat—and I cannot repeat too strongly—that the future of all industry depends on the ability of the maintenance team to keep the wheels turning. He must have the knowledge to do it. By using the many sources of information available to him, he can begin right now, today, to build himself into the maintenance engineer who will be vital to every industry tomorrow.

Additional information for maintenance men:

"Protective Maintenance of Motors and Generators," National Electrical Manufacturers Association, 155 East 44th St., New York 17, N. Y.

"Better Motor Maintenance and Field Testing," A-5009, and "Troubleshooting Manual for D.C. Motors and Generators," Reliance Electric and Engineering Co., 24701 Euclid Ave., Cleveland 17, Ohio.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

New Concept for Automated Roll Handling at Union Bag-Camp Paper Corporation

H. J. SUNDAHL and C. H. EITEL

A conveying system which consists of manually controlled in-floor and automatic and/or manually controlled monorail carriers has been installed at the Savannah plant of the Union Bag-Camp Paper Corp. This system should provide for the efficient and economical handling of approximately 2400 tons of board and paper rolls per day from the seven paper machines to any one or all of the thirteen delivery stations built into the system. The flow of rolls on the in-floor portion of the system is manually controlled by roll handlers and/or scalemen. The monorail portion operates automatically after the rolls are loaded, and the specified discharge point has been set. The system is controlled mostly through electric circuits, however, some control is effected by use of photo electric eyes. The system has been designed to deliver rolls, without auxiliary equipment, from the operating level to the basement level in the paper mill and from the operating level in the paper mill to the operating level in the bag factory. This feature should eliminate the need for additional ramps and/or roll lowerators. Oou system should also eliminate the need for purchasing considerable additional materials handling equipment.

The start up of the seventh paper machine at the Savannah plant of the Union Bag-Camp Paper Corp. caused production to increase from an average of 2000 to 2400 tons of board and paper rolls per day. This increase in production made it obvious that our old roll handling techniques would be overloaded and thus unsafe and that some form of automatic roll handling system had to be provided. After considering the "pros" and "cons" of the various types of conveying equipment available and mainly because of structural modifications necessary with any other type system, it was decided that an automated handling system using an overhead monorail would best satisfy our needs. Our construction and industrial engineers, working very closely with the equipment supplier, designed the overhead portion of the system which has been installed at our plant. The design of the in-floor equipment necessary to serve the overhead portion, as well as supervision of the installation of the entire system was also handled by our construction engineers. Automatic features built into both the in-floor and overhead equipment and the size and complexity of our system make it the first of its kind in the pulp and paper industry. Control features of our system make it possible for us to automatically handle product from each of our seven paper machines to any one or all of the 13 roll unloading stations. The system which has been installed at our Savannah Plant is basically a monorail system, but for the purpose of describing the equipment and its operation it can be broken down into two elemental parts: (1) the in-floor part, which consists of the loading and unloading stations, (2) the overhead part, which consists of the monorail and carriers.

The in-floor part of our system can be broken down further as follows:

A. Loading stations which consist of:
   1. Roller flight conveyers
   2. Bander conveyers
   3. Scale conveyers
   4. Roll ejectors
   5. Live roller roll pick-up stations

B. Unloading stations which consist of:
   1. Belt conveyers
   2. Roller flight conveyers
   3. Up-enders
   4. Tilting tables
   5. Escapement mechanisms
   6. Industrial truck pick-up points

The overhead portion of our system can be broken down further into the following components:

A. Automatic motorized tractors which are equipped with:
   1. Selectomatic controls
   2. Rubber drive wheel
   3. Couplings for attaching roll carriers

B. Roll carriers which consist of:
   1. Roll cradle
   2. Hoist

C. Monorail which consists of:
   1. Rail
   2. Switches
   3. Lift section
   4. Electrical conductors

Because of the physical layout of our plant, it was necessary to install the seventh paper machine in an area remote from machines 1 through 6. In order to service all seven machines with our roll handling system, it was necessary that the system be laid out as shown in Figs. 1 and 2. Figure 1 indicates the layout in the old paper machine room which houses machines 1 through 6, while Fig. 2 indicates the layout in the newly constructed mezzanine and building which houses our no. 7 paper machine. As can be seen from these layouts, individual loading stations have been provided for machines 3 through 7 while the loading stations for machines 1 and 2 have been combined into one unit. It can also be noted from these prints that machines 2, 4, and 6, which are our board machines, have been equipped with automatic roll banders. Since the operation of all six loading stations is, with the exception of the roll banders at machines 2, 4, and 6, identical; this article will describe the operation at only one loading station. There are, however, three different basic types of unloading stations; therefore, three different unloading operations will be presented. In line with this thinking, a description of the equipment installed at one loading station and at three of the 13 unloading stations will be given.

Since the loading station at machines 1 and 2 (Fig. 3) includes equipment similar to that installed at any of the other loading stations, the equipment at this station will be described. Behind no. 1 paper machine running the entire width of the machine is a roller flight conveyer with $3^1/_2$-in. diam. concave rollers 18 in. wide. This conveyer is mounted flush with the floor and is chain driven through a reduction gear by a 1200 r.p.m., 15-hp. electric motor. The conveyer is driven at a speed of approximately 37 f.p.m. Behind no. 2 paper machine and running the entire width of the machine is a roller flight conveyer identical to the one installed behind no. 1 machine. This conveyer feeds a banding conveyer which is a 16-in. wide rubber belt conveyer, driven through a

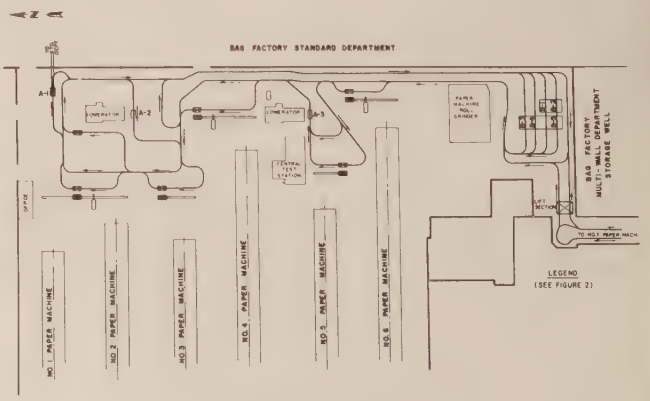

Fig. 1. General layout roll handling conveyor old machine room

H. J. SUNDAHL, Construction Engineer, and C. H. EITEL, Mill Division Industrial Engineer, Union Bag-Camp Paper Corp., Savannah, Ga.

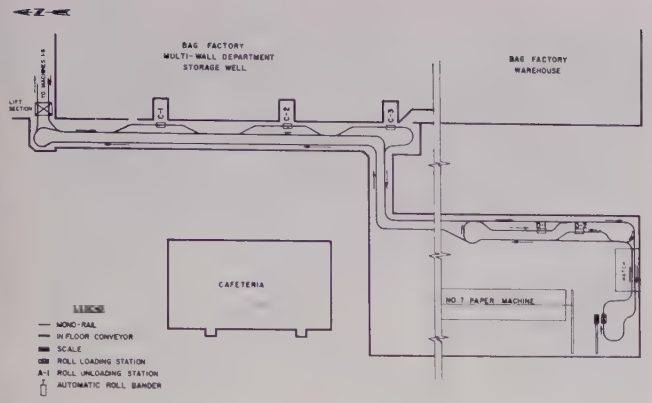

Fig. 2. General layout roll handling conveyor new machine room

reduction gear by a 1200 r.p.m., 2-hp. electric motor. The banders installed in our system are Signode automatic roll banders capable of banding rolls up to 65 in. in diameter. The bander conveyer behind no. 2 paper machine and the roller flight conveyer behind no. 1 paper machine both discharge onto a common scale conveyer which is a 16-in. wide rubber belt conveyer driven through a reduction gear by a 1200 r.p.m., 2-hp. electric motor. The scale conveyor and bander conveyer are both driven at a speed of approximately 43 f.p.m. Our scales are Toledo scales with a maximum capacity of 12,500 lb. and are read in 2-lb. increments. The hydraulic roll ejector built into the scale table consists of a live roller faced kicker arm which is powered by a 4-in. diam. 1000 p.s.i. 10-in. stroke hydraulic piston.

There are three different types of unloading stations. The basic difference between these stations is the type of equipment which receives the roll from the carrier. The three types of roll receiving equipment installed are: (1) rubber belt conveyers, (2) automatic roll up-enders, and (3) tilting tables. Belt type roll receiving equipment is installed at unloading stations A-1 and B-2 as seen in Fig. 1. Automatic roll up-ender receiving equipment is installed at stations B-3, B-4, and B-5 as seen in Fig. 1. Tilting table receiving equipment is installed at all other unloading stations. The unloading system at stations A-1 and B-2 is identical except for length and consists of a 16-in. wide rubber belt conveyer driven through reduction gears by a 1200 r.p.m., 2-hp. electric motor at a speed of 43 f.p.m. This rubber belt conveyer discharges onto an automatic roll up-ender (Fig. 4) which is hydraulically driven by an 8-in. diam. 2 ft. $1^1/_2$-in. stroke piston at a pressure of 1000 p.s.i. The up-enders at both unloading stations are used to affect elevation changes of approximately

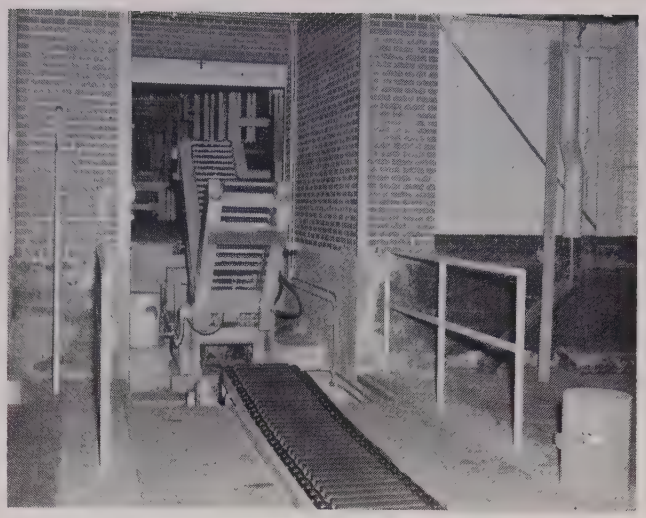

Fig. 4. Up-ender at unloading station B-2 showing elevation change

2 ft. and discharge the rolls, on end, onto a roller flight conveyer with $3^1/_2$-in. diam. rollers 18 in. wide which is driven through a reduction gear by a 15-hp. electric motor at a speed of approximately 37 f.p.m. This conveyer discharges onto an 8-in. wide live roller conveyer which is designed to provide for fork truck pickup of the rolls.

The equipment installed at unloading stations B-3, B-4, and B-5 (Fig. 5) is identical to that just described except that there is no rubber belt conveyer preceding the up-enders and rolls are placed directly on one leg of the up-ender by the carrier. The truck pickup point at these three unloading stations is also slightly different in that instead of the 8-in. wide live roller conveyer the pickup point is merely a sloped steel plate. Rolls from these conveyers are picked up with a "cake knife" equipped fork truck.

All of the remaining unloading stations are equipped with tilting table type roll receiving equipment (Fig. 6). The tilting tables are hydraulically powered by a 4-in. diam. $2^3/_4$-in. stroke piston which operates at a pressure of 1000 p.s.i. At all of these unloading stations, with the exceptions of stations C-1, C-2, and C-3, the tilting table discharges the rolls, on side, onto a ramp equipped with check blocks to facilitate roll pickup by fork truck. Stations C-1, C-2, and C-3 are each equipped with two hydraulically operated escapement mechanisms which control the travel of the rolls down the ramps and allows for accumulation of four sets of rolls. These mechanisms also provide for pickup of the rolls by an overhead crane in the storage well.

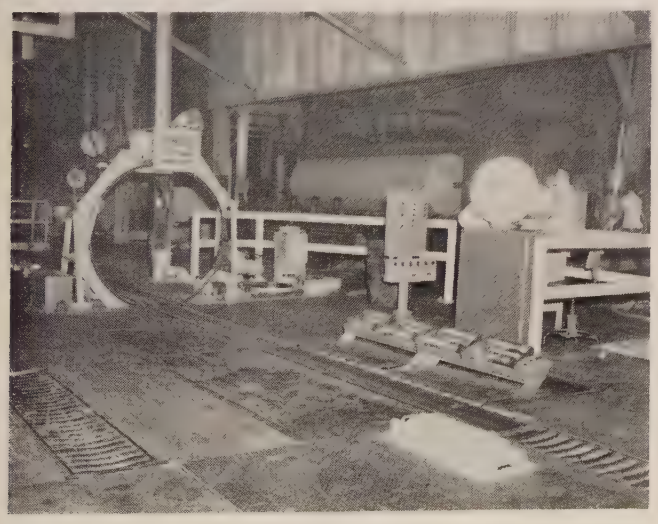

Fig. 3. Roll loading station behind machines no. 1 and no. 2 showing roll bander, scale, and in-floor conveyors

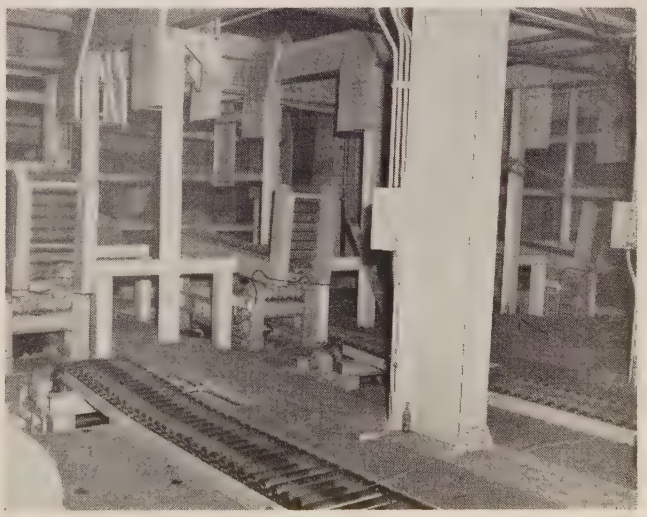

Fig. 5. Up-enders and roller flight conveyors at board shipping area (stations B-3, B-4, B-5)

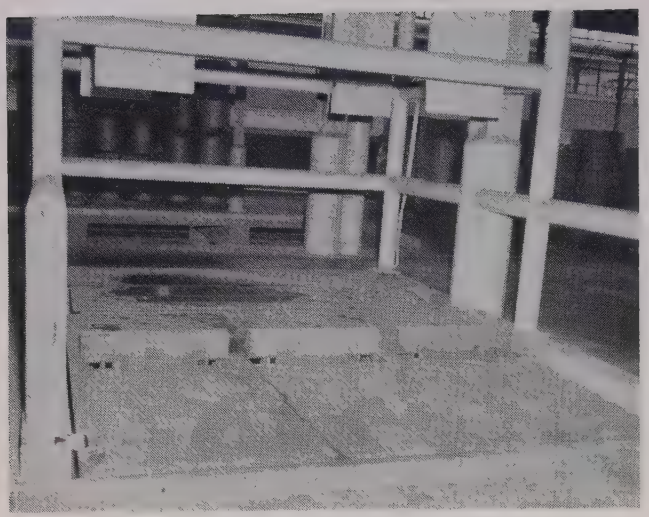

Fig. 6. Typical tilting table roll unloading station

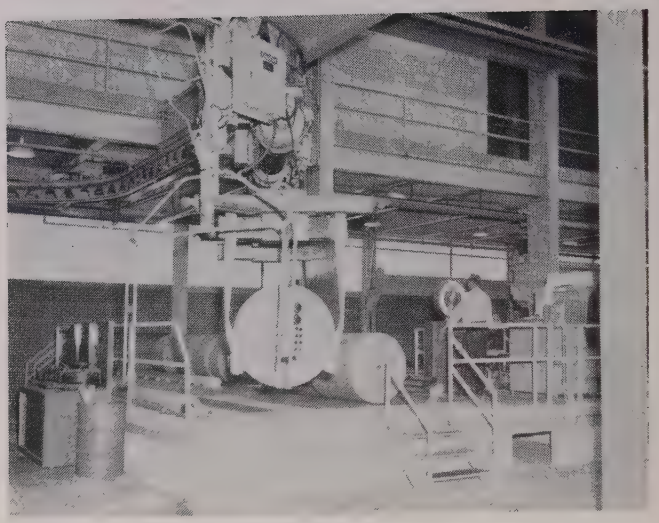

Fig. 8. Loaded carrier leaving no. 7 scale station

The system for all of the hydraulically driven equipment for the in-floor portion consists of three 30 g.p.m. 1000 p.s.i. units, each with an 80-gal. reservoir; and one 70 g.p.m. 1000 p.s.i. unit also equipped with an 80-gal. reservoir.

The receiving equipment at all unloading stations is electrically connected to the monorail to prevent the carriers from lowering a roll when a roll is located in the receiving station. The operation of the drives for the up-enders and the roller flight conveyers is controlled by electric eyes and/or limit switches. The operation of the belt conveyers and tilting tables is controlled electrically by signals received as the carrier passes control points on the monorail. These control features will be discussed further in the section describing the operation of the system.

There are, at present, 18 traveling units (Fig. 7) in operation on our system. Each of these units is made up basically of a motoveyer and a roll carrier. The motoveyer or power unit is driven by a 16-in. diam. solid rubber tired drive wheel which is pressure mounted against the underside of the monorail. This drive wheel is powered through a fluid coupling by a 2 hp., 220 v. electric motor. The units in use at the Savannah plant are designed to operate at a travel speed of 100 f.p.m. Also included as a part of the motoveyer is the Louden Machinery Co.'s selectomatic controls which makes it possible for the carrier to automatically travel to a designated discharge point, discharge the rolls, and then return to a roll loading station. The motoveyer is also equipped with a mechanical coupling for attaching the roll carrier. The roll carrier is mounted on the monorail on 30,000-lb. capacity trolleys and consists of a roll cradle and an electric hoist for raising and lowering the roll cradle. The roll cradle is capable of handling rolls ranging from $19^1/_2$ to 60 in. diam. and from $10^1/_4$ to 96 in. in trim. The maximum weight that can be handled by the cradle is 10,000 lb. The lowering and lifting speed of the hoist, which is driven by a 15-hp., 220 v. electric motor, is 27 f.p.m. The roll cradle is opened and closed through a chain and gear drive by a 1 hp., 220 v. electric motor.

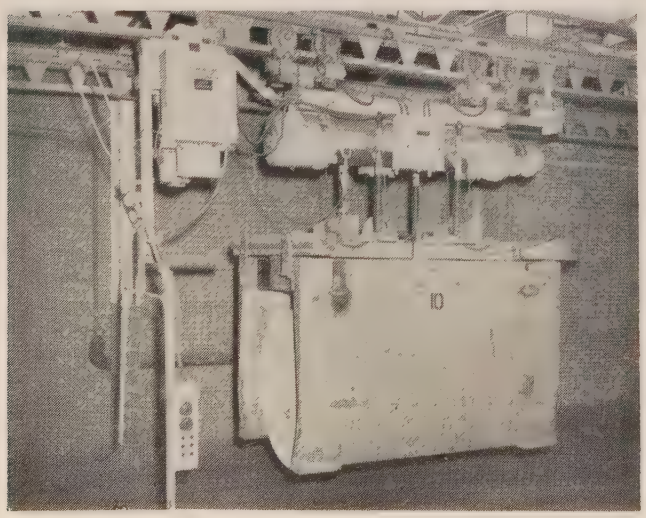

Fig. 7. Typical traveling unit showing motoveyor and roll cradle

The trackage which supports the motoveyer and roll carrier is the Louden Machinery Co.'s "Trojan" rail. This rail is 16 in. deep with a $3^1/_3$ in. wide by $^{13}/_{16}$-in. thick bottom flange. There are 46 glide type switches and approximately 1 mile of monorail installed in our system. The switches provide a smooth tangent when they are positioned to direct the carriers around a curve. Also included as a part of the monorail portion of our system is a hydraulically operated lift section. This section was necessary to enable us to accomplish an elevation change of approximately 7 ft., 3 in. between the new and old machine rooms. The lift section is made up of two parallel 17 ft. long sections of monorail which are raised and lowered by a 6-in. diam. 7 ft. 3 in. stroke hydraulic piston. Mounted on each side of the monorail are two 220 v. electric conductors which furnish the power to, and control the movement of, the traveling units.

In order to describe the operation of the above equipment, a set of rolls will be followed from the time that they are produced on the no. 1 paper machine winder until they are delivered to their ultimate destination. Rolls produced on the machine winder are lowered to the operating floor immediately behind the winder. At this point, the roll handler assigned to the no. 1 paper machine separates the rolls and stencils the basic information on the ends of the rolls. After this is done, one roll, or if the rolls are of narrow trim and the trims are equal, a group of rolls not to exceed a total width of 96 in., are manually rolled onto the in-floor roller flight conveyer by the roll handler. (One important point that must be observed in this phase of the operation is that when a group of rolls are placed together on this conveyer, all of the rolls must go to the same destination.) The roller flight conveyer is controlled by stop-start buttons which are located adjacent to the scale conveyer. In the case of machines 2, 4, and 6, the rolls pass through the automatic banding machines which automatically band the leading and trailing edge of the rolls before they move onto the scale conveyer. The scaleman can, at his option, set controls which will allow rolls to pass through the banders without being banded. After the rolls arrive on the scale conveyer they are weighed and the roll weight and number is

stenciled on the ends of the rolls by the scaleman. The rolls are then moved from the scale conveyer to the roll pickup point by the hydraulic roll ejector which is also operated by the scaleman. While this phase of the operation is being conducted, an empty carrier is normally waiting in the loading siding of the monorail system. The selectomatic controls which are mounted on the carrier are arranged so that empty carriers automatically move into empty roll loading sidings on the monorail system. All loading sidings with the exception of the siding at the no. 6 paper machine have been designed to accept two empty carriers. The loading siding at no. 6 paper machine, because of space limitations, has been designed to accept only one carrier. If all loading stations are filled with empty carriers, any remaining empty carriers will continue to circulate around the main loop until room becomes available at one of the loading sidings. The controls have also been setup so that the first empty carrier in a loading siding will automatically stop before reaching the actual roll pickup point. From this waiting position, the carrier must be moved to the roll pickup point by operating the manual controls. Manual controls have been provided to move the carrier forward, backward, up, down, open, or closed. The scaleman or roll handler, by use of the manual controls, moves the carrier to the roll pickup point, positions the carrier, and closes the roll cradle. (Empty carriers travel with the roll cradle in the full open position.) He then designates the station to which the carrier should deliver the rolls. This is done by setting two dials on the selectomatic control panel which is mounted on the carrier. The first dial designates the area, the second dial designates the station within the area. As can be seen by the numbering of the unloading stations in Figs. 1 and 2, there are four areas within our system. These are designated as areas A, B, C, and D. Within area A there are three delivery stations, A-1, A-2, and A-3. Figures 1 and 2 indicate the number of stations within the remaining three areas. In order to send a roll or a group of rolls to station A-1, the scaleman would set the area dial on A and the station dial on 1. The controls built into our system provide for two additional areas and as many as six unloading stations within each area.

After the area and station dials are set and the roll cradle is closed, the scaleman then pushes the start button. From this point the operation of the carrier is completely automatic until it returns to a loading siding. After the start button is pushed, the carrier automatically raises the rolls to the travel position and moves away from the roll pickup point (Fig. 8). Immediately after leaving the roll pickup point, the carrier passes a control section in the electrical conductor which is mounted on the monorail. If the track switch which connects the loading siding to the main line is clear, it is automatically moved into position so that the carrier can enter the main line from the loading siding. If the switch is not clear or if another carrier is passing through the switch on the main line, the carrier leaving the loading siding will automatically stop until the switch becomes clear. Immediately after the loaded carrier or any carrier passes through the switch, it passes another control point in the electrical conductor which clears the switch and makes it available for any carriers following on either the main line or from the loading siding. In this same manner the loaded carrier selects and throws switches to take it via the shortest route to the designated unloading station. If the unloading station is clear, the carrier will move into position over the roll receiving point, will automatically stop, lower the roll, open the roll cradle, and then raise the cradle to the travel position. The rolls will remain in the roll receiving station until the roll cradle is raised and the carrier moves across another control point on the electrical conductor which will transmit a signal to the roll receiving station and cause it to operate.

As previously mentioned, there are three basic types of roll receiving stations installed in our system. Belt-type roll receiving equipment is installed at unloading stations A-1 and B-2. Automatic roll up-ending receiving equipment is installed at unloading stations B-3, B-4, and B-5 and tilting table receiving equipment is installed at all other unloading stations. Rolls delivered to station A-1 are placed by the carrier onto the in-floor belt conveyer. There rolls depress a switch which transmits a signal to the electrical conductor mounted on the monorail and causes the roll cradle to open. After the cradle is fully opened and the roll is placed on the receiving station, the carrier automatically leaves the area as previously described. When the carrier passes a control point in the electrical conductor mounted on the monorail and the up-ender at station A-1 is in the receiving position, the in-floor belt conveyer automatically starts and carries the roll to the roll up-ender. Immediately before entering the roll up-ender, the roll passes through an electric eye. This electric eye provides a safety feature in that if a roll is blocking the eye, the up-ender will not operate. The roll then advances onto the up-ender until it strikes a switch on the bottom leg of the up-ender. This causes the up-ender to automatically up-end the roll. The pivot point of the up-ender is so located that the up-ender is used to lower the rolls approximately 2 ft. below the operating level in the paper mill to the operating level in the bag factory. The rolls are then gravity fed from the discharge leg of the up-ender onto a roller flight conveyer. In leaving the up-ender, the rolls pass through another electric eye which automatically starts the roller flight conveyer. This conveyer carries the rolls, on end, to a fork truck pickup point which is located at the end of the conveyer. The roller flight conveyer has been designed to run for a period of $1^1/_4$ min. or until rolls block two additional electric eyes which are located at the fork truck pickup end of the conveyer.

When a roll is delivered to stations B-3, B-4, or B-5, it is placed directly onto the receiving leg of an automatic roll up-ender. There is an electrical switch mounted in this receiving leg which transmits a signal to the electrical conductor mounted on the monorail and causes the roll cradle to open. One basic difference in this receiving station is that it is located in the basement of the paper mill approximately $12^1/_2$ ft. below the operating level of the paper mill. Rolls are lowered to this unloading station by the hoist which is mounted on the roll carrier. After the carrier deposits the roll on the up-ender it automatically raises to the travel position and advances along the monorail. The up-ender is activated as described above and automatically up-ends the rolls and discharges them by gravity onto a roller flight conveyer. From this point the operation is similar to the operation following the up-ender as just described for unloading station A-1.

The remaining unloading stations are equipped with tilting table-type roll receiving equipment, and operate as follows: rolls are placed by the carrier into a trough type tilting table. This table is equipped with an electric switch which transmits a signal to the monorail and causes the roll cradle to open. After the cradle is fully opened and the carrier deposits the roll in the tilting table, it automatically raises to the travel position and advances along the monorail. It passes through a control point in the electrical conductor and causes the tilting table to dump the rolls, on side, out onto a ramp. The rolls roll down the ramp and at the bottom are picked up by a "cake knife" equipped fork truck. Stations C-1, C-2, and C-3 are equipped with roll escapement mechanisms which act to control the flow of the rolls down the ramp and also separate the rolls so that they may be picked up by overhead cranes.

The controls and layout of our system have been set up so that rolls from any one of the seven loading stations can be sent to one, or all, of the 13 unloading stations. By use of this system it is felt that the 2400 tons of paper and board rolls produced daily by the seven paper machines at the Savannah plant of the Union Bag-Camp Paper Corp. can be efficiently and economically handled.

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Fabrication of Plate Structures for Paper Mills

ROBERT A. DAVIS

Paper mill engineers, those concerned with the purchasing of plate structures, and others who are interested somewhat in the details of the fabrication of these structures will find in this paper a step-by-step description of the fabrication. On a figurative "tour" of a fabricating shop we follow through from unloading to the various stages of edge preparation, forming, assembling, welding, radiographing, stress relieving, testing and shipment of typical vessels such as digesters. Good fabricating practices are discussed, including many steps that reliable fabricators take in the best interests of their customers. These may include material selection, good design, careful workmanship, and adequate testing. While molded around a specific plant the paper is quite representative of fabrication practices in any other typical reputable fabricating shop.

LET's take a quick "tour" through a modern, heavy steel plate fabricating shop—one such as might be making digesters, evaporators, tanks, or other plate work for paper mills much like yours. (Parenthetically, it is natural to add that such work is always welcomed!) Work description, machinery, and procedures will apply specifically to the Birmingham plant of Chicago Bridge & Iron Co., but are quite typical of other similar plants. No apology seems necessary if procedures differ in minor detail from methods used by others.

A few years ago, our TAPPI Corrosion Committee sponsored publication of TAPPI Monograph No. 12 entitled "Inspection of Digesters." Included in the appendix was a section "Construction Materials & Manufacture," with which there may be minor overlapping comments.

Soon after receiving an order, a fabricator in turn orders the necessary steel. Let's digress a bit to touch upon the subject of steel specification, particularly for kraft digesters. This has been, and to a small degree still is, a controversial subject, which is understandable, and perhaps justifiable. Paper mill engineers will probably agree that there *is* no one-and-only proper steel for a digester. Conditions differ also, as to whether the optimum economy will favor carbon steel with a substantial corrosion allowance, or steel clad with stainless or inconel.

TAPPI Monograph No. 12 discusses various grades of steel in considerable detail, which need not repeat here. For carbon steel, suffice to say that the formerly frequent use of the higher tensile grade ASTM A-212 steel has gradually been discontinued, except as backing for clad steels. ASTM A-285 steel has generally come to be used predominantly, usually in the firebox quality, grade C, with 55,000 p.s.i. minimum tensile strength. A few mills favor the lower tensile grades A or B. There has been evidence that corrosion rates increase with increased silicon content, so fabricators make efforts to obtain steel with a low silicon content. Other normal elements seem to have but little, if any, effect upon the corrosion rate.

When clad plates are specified, type 316L, a molybdenum bearing austenitic stainless of very low carbon content, is the most frequently used. Also several digesters have been clad with Inconel, which costs more and has a still lower corrosion rate. Material choice is largely the decision of the purchasing paper mill, based upon their individual knowledge ahd experience. It is well known that there is such a wide and erratic variation in types and severity of corrosion attack, as to justify placing most dependence upon their individual experience, rather than upon mill averages.

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Due in part to information and help made available by the efforts of the TAPPI Corrosion Committee, average corrosion rates are now reported at considerably lower levels than a few years ago. The median average for all reported carbon steel kraft digesters was recently down to about 22 mils (0.022 in.) per year, with clad digesters averaging near a low 1 mil per year. Critical areas in carbon steel average dabout 60 mils per year, stainless clad about 3 mils, Inconel about 2 mils per year, all based upon the report entitled "Current Status of Alkaline Digester Corrosion" as presented by the Corrosion Committee at the annual TAPPI meeting in February, 1959, and as published in *Taypi*, May, 1959.

As expected, there were rather wide variations reported, both in carbon steel and in clad, and particularly in previous reports, the Inconel clad averaged considerably lower rates than even the stainless clad. One important conclusion of the several studies was that variations in operating procedures affected corrosion rates much more than differences in steel.

Generally, fabricators do not now recommend special or proprietary steels, though there have been exceptions. One of our published committee reports, based upon studies of corrosion rates, concluded that ". . . it appears . . . that both the high tensile carbon-silicon steels, and the special modern rimmed digester steels tend to have inferior rather than superior corrosion resistance, as compared to the more commonly used . . . A285C."

Now, let's follow the actual fabrication procedure for a typical carbon steel digester right through the shop (Fig. 1). Steel arrives, mostly cut to rectangular shape, but neither exactly squared nor to exact sizes. It is unloaded from gondola cars by magnetic lifts, and overhead traveling cranes. Each plate is first checked for size and squared, to make sure it will finish to the required dimensions. Thickness is checked by micrometer at various points, and a careful check is made for any possible defects or laminations. Each plate is then accurately layed out according to dimensions on approval drawings, including all necessary information for edge preparation, type of weld groove, and with sketches as may be necessary, on the plate.

Plates to be formed only to a cylindrical or conical shape, commonly referred to as "single curvature," are laid out in the flat, using dimensions equal to centerline dimensions after forming. Plates to be "dished," such as hemispherical or elliptical heads, or for knuckles or spherical portion of bottom cones, commonly called "double curvature," are layed out after forming. This provides for the required accuracy that might be lost during forming, due to distortions from stretch during forming to the double curvature.

Straight edges on cylinder or cone plates may be either planned or burned to exact size and joint detail. Sometimes several torches in a single mounting may be used, to produce the desired welding grooves in a single pass. Double curva-

Fig. 1. C.B.&I.'s "typical" fabricating plant at Birmingham

Fig. 2. Automatic welding digester girth seam

ture plates are usually burned, manipulating the formed plate as required while the automatic burning head progresses.

Thinner plates are curved to cylindrical shape by rolling, after first "setting" the ends on a press to assure proper curvature for the full length. The end housing on the rolls drops down so that a plate may be rolled to a complete circumference in one piece, then removed over the end of the rolls. Heavier plates, such as for a typical 2-in. thick digester shell are now generally pressed to shape on a hydraulic press, especially designed for the purpose, which is somewhat unusual in that it was designed to permit a full 360° shell plate to be made with a single longitudinal seam, when plates large enough are obtainable.

The longitudinal seams of each ring are welded first. The outside of the seam is usually welded by a submerged arc automatic type welder, either with a single pass or multiple pass as may be required, or depending upon the thickness. The automatic welding head may travel on a fabricated track above the seam being welded, or may be carried on a traveling gantry. Then the inside of the longitudinal seam is welded in a somewhat similar arrangement, the welding head usually traveling on the steel itself as shown in Fig. 2. The inside weld of the same submerged arc type as the outside, may be for the full thickness of the plate, but more frequently, is only welded to within approximately the corrosion allowance of the inside surface of the plate. In this case the inside welding is completed by manual deposits.

There is a very good reason for this. Information coming to the Corrosion Committee over recent years has indicated that in many cases manual welds on the inside corrode at a slower rate than welds made automatically. This is usually considered to justify the extra cost of the hand welding on the inside for the approximate depth of the corrosion allowance. In many cases, digesters made of thicknesses up to 2 in. have a corrosion allowance of up to something over a full inch, in which case the hand weld may be made to a depth of perhaps $^5/_8$ in. for optimum economy.

The completed individual rings are usually fit together on a set of rolls, accurately aligned, which in turn assures that the shell itself will be in a straight line. After being properly assembled and pulled tightly together, the rings are tack welded while on the alignment rolls, then removed to another set of motorized rolls for welding the girth seams (Fig 2). These seams are welded by rotating the entire shell, using automatic or hand welding as required, the same as on the longitudinal seams. Part of the flux used in making a submerged arc weld is solidified and lost as slag, the balance is reclaimed and used again.

Elliptical, hemispherical, or flanged and dished heads are usually formed by hydraulic presses in the fabricators' shops. Some fabricators purchase their formed heads from steel mills that have spinning equipment. All fabricators may so purchase part of their head requirements, depending upon current work load or forming equipment available in their shop.

The head attachment seam, or occasionally one of the other girth seams, becomes the final closing seam. This seam is differently prepared in advance to provide the proper weld grooves since it must all be hand welded on the inside.

When local radiography is used, each seam is marked off in short lengths to identify the locations of the radiograph or x-ray films to be taken of the welded joints. These lengths are first identified by chalk, then stamped permanently into the plate by number and identification. Each location is then further identified on the film itself by attaching lead letters to the steel with adhesive tape. The lead letters register on the film by being more opaque to the x-ray and of course agree with the permanent stampings in the steel to locate and identify each film. Films are frequently held to the inside of the shell by magnetic holders, easily placed.

On a portable x-ray the controls are in a lead lined booth for the protection of the operator. However, most of the x-ray films made today in a modern fabricating shop are made in a special building with thick concrete walls to reduce the heavier radiation to acceptable limits for any persons nearby. The 1,000,000 and the 2,000,000 x-ray machines at Birmingham are housed in a building with 48 in. thick solid high-density concrete walls. Entrance is through a maze with similar walls, there are many safeguards to eliminate any chance of an accidental personal exposure. The 1,000,000 v. machine photographs an entire girth seam from the center of the vessel with a single exposure, the film strip simply being wrapped around the outside. The 2,000,000 v. machine takes the full length of a longitudinal seam in a single exposure, from a sufficient distance to avoid distortion of the image.

Whenever the film discloses any defect such as a crack, or porosity of the weld beyond minor acceptable limits, the location is identified on the vessel. The defect is then chipped, or gouged out, down to sound steel, repaired, and an additional x-ray is taken to verify the integrity of the repair.

Figure 3 shows a typical view inside the welding shop, with a relatively full work load.

With the main part of the vessel now assembled, we turn to the fabrication of the various fittings. The flanges and the reinforcing plates for the various nozzles are burned by a machine with automatic travel. This machine can either follow a circle by pivoting about a center, or it can follow a previously made templet for any odd shape such as would be required for the reinforcing plates of an off-center or tangential nozzle. If several identical odd shapes are to be

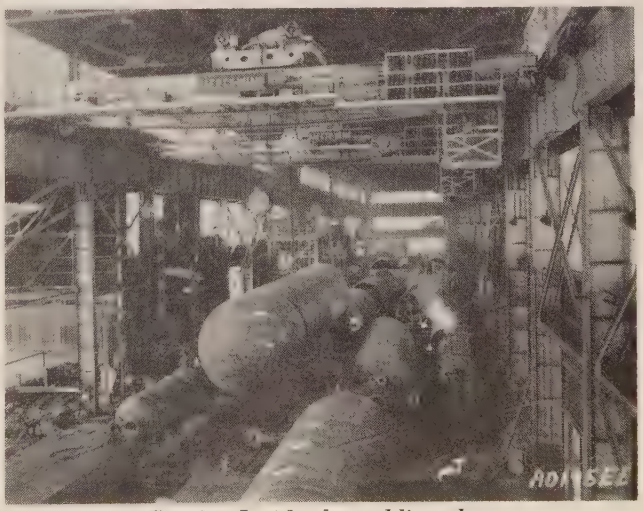

Fig. 3. Inside the welding shop

made, several can be burned at the same time with multiple torches mounted on a machine called a pantagraph, which follows a previously made templet.

Nozzle necks and flanges are assembled, first tack welded into place, then automatic welded on a rotating positioning machine. Multipass submerged arc welding is normally used, and after each pass the excess flux and slag must of course be removed. Both the gasket side and the back side of the flange are similarly welded, in properly prepared grooves, tilting the rotating positioner whenever required to facilitate the welding. The assembled nozzle then goes to the machine shop for facing, turning, and drilling.

The gasket face may be of the phonographic type for gasket retention, or may be very highly polished, such as for example the groove for a ring-type metallic gasket. The bolt holes are drilled to a templet, and the layout is carefully checked before the actual drilling begins. Frequently, ultimate economy dictates the drilling of a small pilot hole first, followed sometimes by an intermediate size and, of course, by the final full size drilled hole. The other end of the nozzle must frequently be cut to the contour of the cylindrical shell to which it must fit, an operation also done mechanically.

Although the fitting locations and holes are usually layed out for field erected vessels while the plates are in the flat, they are usually layed out on the completed vessel for shop built-up vessels. Centerlines must be accurately established on the assembled vessel. From these centerlines all the vessel fittings will then be carefully located. Initial chalk lines locating the openings must be substantiated by center punch marks before the openings are burned, as the chalk mark would otherwise be lost during the burning and the center punch marks are necessary to preserve it accurately for the burner. Proper cutouts are made for the various nozzles and at the same time locations are established, if required, for any necessary clips. Such clips are not often required on such as a paper mill digester, but on similar built-up vessels, such as petroleum refinery towers, there are often platforms or ladders which must be supported from the vessel itself.

Reinforcing plates around the openings are usually located and tack welded in place before the actual nozzle is placed. Heavier nozzles are lowered in place by overhead cranes, whereas the lighter fittings can be handled manually. Each fitting must be carefully leveled and aligned, and the fitting face must be accurately held to the proper plane before it is welded into place. This assures minimum difficulty in connecting pipelines at the final destination, since such lines may even be prefabricated based upon the predetermined dimensions.

A final check by magnetic particle examination is then made, particularly of the welds around the fittings, which

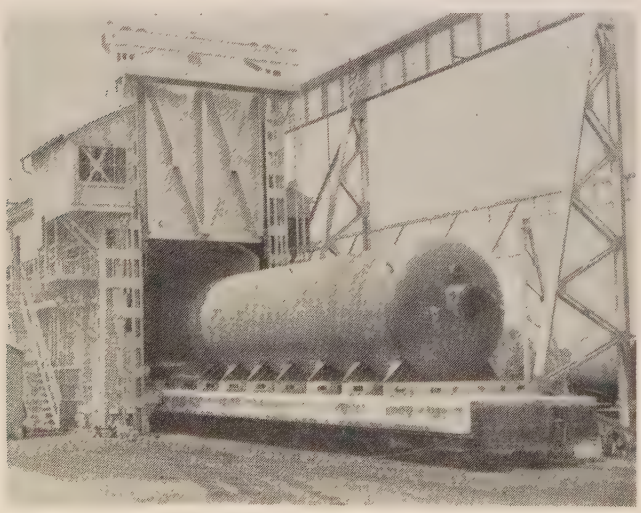

Fig. 4. Stress relieving furnace

Fig. 5. Section of clad weld

cannot be effectively radiographed. The arrangement of magnetic iron filings will disclose any cracks, even beneath the surface.

If there are any internal parts to be installed, such as strainer rings or spray rings, this part of the work is done last to complete the vessel. Paper mill digesters usually do not have much complicated internal work such as the dozens of bubble trays which represent the appreciable proportion of the work in a fabricating shop on some other types of vessels.

Digesters are usually stress relieved in a typical furnace such as is shown in Fig. 4. A normal stress relief amounts to heating the entire vessel, with careful controls for uniformity, to a temperature of about 1150°, holding for 1 hr per in. of thickness, then slowly and uniformly cooling. This very largely relieves any localized stresses which would otherwise remain, as a result of contraction from the cooling of the welded seams. Lower temperatures and longer holding periods are alternately permitted by the applicable code.

The stress relieving furnace is lined with refractory brick, and the vessel is loaded on a special car which has a refractory brick top that becomes the bottom of the furnace. This furnace is divided into 12 separate zones each of which can be accurately controlled to keep the entire furnace of closely uniform temperature. Several thermocouples are also attached to the vessel itself, to control the temperature of the steel to close uniformity. A permanent recording of the stress relief cycle is kept.

Insufficient care or control of the stress relief operation could leave the steel in less than optimum condition. Unequal heating or cooling could in itself establish a set of stresses. This justifies the multiple controls and recordings of the various thermocouple readings.

Before shipment, each pressure vessel, such as one of your digesters, is tested hydrostatically. The manhole cover is bolted in place, blanks attached to all the other nozzles, and hydrostatic pressure, usually $1^1/_2$ to 2 times the working pressure, is then applied. Careful check is made using duplicate gages, and also a recorder which gives a permanent record of the test. After testing, the vessel is emptied, usually speeded by applied air pressure inside, or by assistance of a large siphon. The manhole or charging nozzle cover is then reopened and the vessel cleaned inside if required. Before loading and painting, the outside is also cleaned, with a power wire brush, to remove all loose scale. The vessel is then ready for loading on railroad cars for final shipment.

Longer vessels must of course be loaded on two cards or more, using a swivel bolster so that in transit the cars may properly negotiate the railroad curves. Painting, whenever required, is usually done after loading on railroad cars, frequently by spray.

Having figuratively followed a typical carbon steel pressure

vessel, or digester, through the shop, let's now look at some of the special work. Most fabricators make varying quantities of solid stainless or clad stainless vessels. Some are also built of special high-nickel alloys such as monel, Inconel, or pure nickel, the Hastelloys, solid aluminum, copper, and other special or proprietary metals.

Until recent years most clad plate was made by the hot rolling process. Hortonclad is now made at Birmingham by a patented high-vacuum furnace bond, whereby the tolerances of the clad thickness are limited to the close tolerance to which the alloy sheet is rolled. This versatile process permits cladding of some of the more unusual metals not otherwise available, and even the backing plates may be stainless or nonferrous as well as steel. This multiplies tremendously the possible clad plate combinations available through Hortonclad.

Clad plate can be hot or cold formed into all normal shapes required in the manufacture of large containers and pressure vessels. Hemispherical, ellipsoidal, or dished and flanged heads are regularly produced as well as shell rings. Because of the excellent high temperature bond strength, normal hot forming is easily performed.

Welding the formed plate is easily performed when normal precautions for welding dissimilar metals are observed. Figure 5 shows a typical section of a welded joint.

To make such a composite weld, the abutting edges of the mild steel are beveled to leave an hour-glass shaped gap. This applies to the heavier composite plates, and becomes only a single bevel for the thinner plates. The stainless cladding is usually cut back slightly beyond the mild steel bevel. The mild steel is then welded halfway through from one side, and the remainder of the weld is applied from the opposite side. The important consideration is that the carbon steel weld should not pick up any of the stainless, or the dilution will produce a brittle intermetallic structure.

Some fabricators prefer to have a heavier abutting edge using a single bevel without originally chipping back the cladding, so that the carbon steel weld will not penetrate into the stainless. The same end result is then accomplished by adequately chipping out from the stainless side, and completing the weld with the proper alloy rod. A mild dilution of the alloy weld with carbon steel does not produce the same brittle condition. A properly enriched alloy rod is used so that the resulting deposit will be of correct composition.

When welds are to be examined by radiography they are usually checked for soundness by x-ray machines before the stainless overlay is applied, so that, should any repairs be necessary they may be made before the alloy weld is made. Additional x-ray examination is made after the clad is welded, if it is included in the design thickness.

Alloy or clad vessels, from start to finish, require more protective care than steel vessels. Surfaces can become easily contaminated by iron or steel particles if not properly protected. Although not usually considered necessary for a digester, some of the more severe chemical services may require the use of heavy paper or plastic between the alloy and all parts of the machines when forming, plus the additional necessity of chemically iron-freeing of the surface after fabrication is complete. Sometimes a complete passivation of the surface may be specified.

Though some has been done, stainless overlay of digesters is not usually considered in normal shop fabrication of new digesters. But when digesters have corroded to near their minimum permissible thickness, a stainless field overlay offers much economy in greatly extending the life of existing vessels. The art has now been developed to where many of the earlier difficulties have been satisfactorily solved, and a reasonable life for the overlay can be expected with considerable confidence.

Many paper mill structures, from storage tanks to the more complicated blow tanks or process towers, are usually of a size to require field erection. Up to the point of shop assembly, the shop fabrication is essentially the same as described for the smaller vessels. Competent field crews and equipment are maintained to assemble, weld, and test the larger vessels in the final locations at the paper mills.

A tendency toward somewhat accelerated corrosion has been reported in some kraft digesters wherever shop assembly parts had been welded, then removed, and areas ground. For this reason, fabricators should try to hold to a minimum the number of temporary shop fitting gadgets, and to reduce grinding on the inside surfaces, so far as practical.

While we are still on this shop "tour," we might notice many interesting structures other than for paper mills, in the process of fabrication. Included might be cryogenic tanks for liquified gases at missile bases, the inside tank being of aluminum or stainless, or wind tunnel plates of channeled Hortonclad for forced cooling, or plates for the huge atomic energy containment vessels such as the 225 or 190-ft. spheres. The picture varies greatly from week to week in any typical fabricating shop.

Fabricators take pride in their safety records. Hazards exist in industrial plants; and this is especially true in this type of work. Carefully planned safety programs have enabled the Birmingham plant to win various safety awards, once going over 3 years without a single lost-time accident, plus many commendable periods of shorter duration.

To produce a pressure vessel or digester of high quality, reputable fabricators fully recognize that proper care must be taken throughout the fabricating processes. Accuracy of dimensional layout, care in forming, and in fitting, are each important in producing the ultimate desirable roundness, alignment, and dimensional accuracy of the finished vessel. Probably most important of all is the proper and careful welding of all the joints, upon which the strength and integrity of the vessel depend.

The welding engineer has considerable responsibility in the exact choice of the best welding rod and flux, particularly of the proper current, and in fact the whole welding procedure. Usually multipass welds are considered better than heavy single-pass automatic welds. Qualification tests, probably beyond the requirements of any applicable code, are carefully observed before each operator is permitted to weld on the vessel itself. Every possible skill and precaution must be used to produce sound welds, free of flaws and cracks. Experience and knowledge are very important factors when welding important pressure vessels.

Adequate laboratory facilities are maintained for research, development of welding procedures, testing, and cladding experiments. This includes equipment for physical tests, chemical analyses, impact testing down to temperatures as low as 300° F., microscopic, metallographic, and spectrographic analyses, and accelerated corrosion testing. A capable staff of experienced graduate engineers checks all phases of design, and special process engineers take responsibility for performance of such items of equipment as evaporators. Most contracting engineers have a background of shop, field, and engineering experience, to qualify them for reliable consultation on customer's requirements.

Of importance also, is the great care with which the inspectors check dimensions, and search for any hidden crack or defect which could later instigate a larger crack in service. Sometimes unexplainable little things go wrong in service, even with the most careful fabrication and inspection, so all the effort to turn out perfect work is well worthwhile. There are many reputable fabricators, and as in other products the final quality may depend much more upon the confidence that can be placed upon the reliability and integrity of the fabricator, than upon the purchaser's meticulous choices of specifications, checking, and inspection. The record is good, and we all want to keep it that way.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–29, 1960.

Conveying and Storage of Clay

H. A. STOESS, JR.

With the expanded use of clay in the paper and board industry, many problems arise in the handling of this important raw material. These problems include discharge from bins and weighing. Information required to design a clay facility is based on the formula:

What + When + Where + How.

Then type of storage, i.e., dry or slurry. This paper deals with many of the problems, discusses design information and relates development from bag to slurry storage.

EXPANSION in the use of coated papers and board has increased the consumption of clay by our pulp and paper industry to close to 1 million tons per year. To receive, unload, store, and feed this clay to our processes requires conveyors, storage bins, and measuring equipment adapted to the physical characteristics of the material itself. Depending on its purpose, clay is produced by the mines in various physical forms and shipped to our mills. These forms include air floated and water washed, both lump and pulverized, spray dried and slurry.

In determining our handling and storage system, let us consider the formula "What + When + Where + How = The Facility." "What" is the physical and chemical properties; "When" is the timing of the various components to the facility; "Where" is the location of the various operations, i.e., receiving, storage and use or mixing point; and "How" is what do we use for the storage and handling; with the sum of these equal to the determination of the handling and storage system or "Facility."

"What" is clay. The American Ceramic Society gives the following definition of paper clay. "A white clay, very low in free silica, and usually having a small particle size as marketed. Because of its high retention, color and suspending properties, it is used for filling or coating paper. Most paper clays as put on the market are beneficiated products." With the various physical forms, there are likewise various physical characteristics (Table I) for both filler and coating grades. Air floated clays are very light and fluffy since they are produced by a completely dry refining process. The water washed grades are slurried and then classified according to particle size and are furnished in either extruded or so-called lump form, or put through a pulverization process. Spray dried is exactly what its name implies, dried in a spray drier with the product in the form of small hollow spheres Slurry form is high solids (i.e., 65 to 70%) clay water slurry.

Table I

	Bulk density, weight per cu. ft.	*Moisture, %*
Filler Grades		
Air floated—pulverized	30	1–3
Water washed		
Lump	50	2–6
Pulverized	40	1–4
Coating Grades		
Water washed		
Pulverized	25–40	1–4
Lump	45–60	2–6
Spray dried	50–55	0–1

"When" is the timing of the facility. In any bulk handling and storage system, the first consideration is amount of usage, present and within the foreseeable future. From this figure is determined size of storage and number of carloads received per week, which in turn determine the rate of conveying into and out of storage. As a good rule of thumb, a usage of at least 1 carload per week is necessary to amortize adequately a bulk handling system.

"Where" is the location of the bulk handling storage and conveying system. In existing mills, many times this is located where space is available, with little or no thought given to the material handling system to be used. In determining where to place the facility give consideration to conveying distances involved if dry clay and pumping distances involved if slurry is used in delivering to the pulping and refining operation. Since materials handling is one of the greatest costs of manufacture, it is imperative that the facility be designed with the most economical handling system not only in initial cost or capital expenditure, but also in operation and maintenance.

"How" is what we use to unload, store, and mix the clay with water, and put it in the final product. This is determined by a study of the various methods in use and their adaptability and economics to the requirements of the facility.

Before the clay can be handled and stored at the mill, it must be received in one form or another. According to a recent survey 85% of the clay purchased by mills is received in bulk carload and 15% in paper bags. There is, however, a considerable amount purchased in slurry form of 70% solids. Most of this slurried clay is being shipped to Southern mills where weather conditions permit this type of shipment in tank cars. Northern and Western mills find winter a deterrent to this method due to freezing during transit. However, your method of receiving should be determined by an economic survey. Freight rates and distance between supplier and mill should be weighed against the capital expense of the mill facility together with differences in power and maintenance costs for the different types of facilities being considered.

If clay is now received in bags, no doubt the amount of usage does not merit going to bulk. However, since a net saving of $5.00 per ton is realized in the cost of bulk material, the possibility of bulk handling should not be overlooked. Dry clay, in bulk, is received either in box cars or covered hopper cars, or possibly by specialty cars such as the Airslide or Dry-Flo cars. Usually clays having a moisture content of above 1% are handled in box cars and below 1% in both covered hopper and box cars. Grades shipped in covered hopper cars include air floated and spray dried. However, check with your supplier.

In the handling of bag clay from cars to storage and from storage to mixer no special problems exist. Usually hand trucks and fork lift trucks are used. In feeding the mixer, the amount made into slurry is measured as a number of units with a unit equal to a single bag, whether 50 or 100 lb.

In the handling of dry bulk clay from cars to storage and out of storage to mixer, various methods are used. In the unloading of box cars we find mechanical and pneumatic conveyors being used, and in a few instances manual labor. In a previous survey it was found that manual labor using wheelbarrows and handscoops cost $1.65 to unload a ton of clay whereas using scoop trucks and mechanical conveyors, and pneumatic conveyers, cost 29 and 30¢ per ton, respectively. Covered hopper cars are unloaded by mechanical and pneumatic conveyers. Carver and Foote report an average rate of a pneumatic unloading system of about 7.5 tons per hour for box cars, or drum or tunnel dried clay in hopper cars. With the same system, spray dried clay in hopper cars can be unloaded at an average of 10 to 11 tons per hour with the best effort being somewhat in excess of 13 tons per hour.

Dry clay is stored by various methods. First is the flat storage area and then vertical bin. Methods of bin with-

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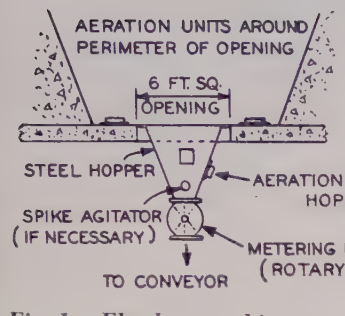

Fig. 1. Flat bottom bins

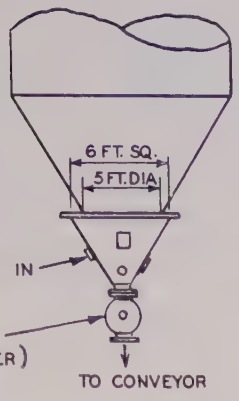

Fig. 2. Cone bottom bins

drawal were developed that have overcome the hanging up of clay in vertical bins that allowed their use, Figs. 1 and 2. Type of vertical bins in use include steel, reinforced concrete, concrete stave, tile and "Perma-Glass." With the use of flat bottom bins, there is considerable dead storage. This can be minimized by using aeration above the floor of the bin. In vertical storage bins with cone bottoms, rat holing is found to be extremely prevalent. Hang up of clay along the vertical walls of silos and bins occurs due to the frictional resistance or surface tension of the clay particles themselves and a high angle of repose, Fig. 3. By adding aeration pads around the perimeter of the bottom cone in the form of a helix, Fig. 4, the surface tension is broken as well as the frictional resistance causing the clay to flow out more evenly across the bin. While this does not eliminate rat holing completely, it does control it to a very great extent.

When storing high moisture clay (6 to 10% moisture) in vertical bins a word of caution is necessary. It has been found that when the bin is more than half full that the moisture in the upper levels dissipates from these levels to the clay at the bottom of the bin. This causes higher moisture at the bottom, usually 25 to 50% more than at the upper levels, thereby causing withdrawal difficulties.

In determining the size of a storage bin, it is usually best not to use the actual bulk density of the clay being stored. Most clays aerate during handling which decreases bulk density by as much as 25%. In fact, in the handling of spray dried clay with a medium velocity pneumatic conveyer, the spheres are broken, and upon discharge from the conveyer, the bulk density is reduced by as much as 50%.

From storage, dry clay is usually delivered to a weigh

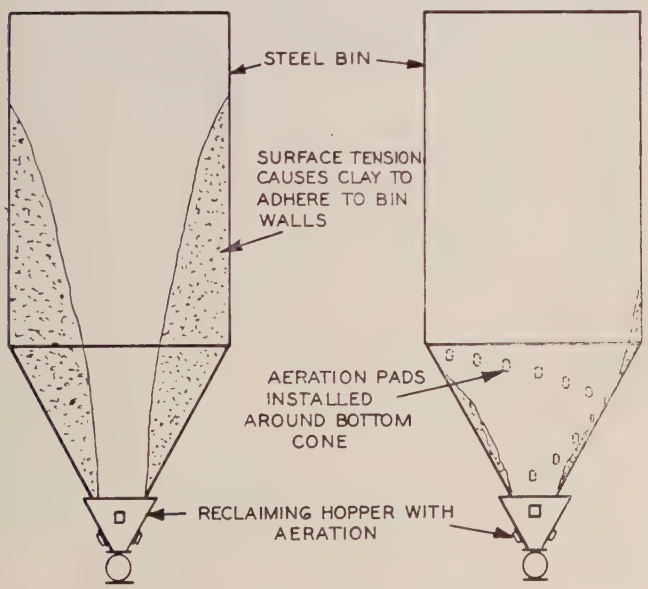
STEEL BIN
SURFACE TENSION CAUSES CLAY TO ADHERE TO BIN WALLS
AERATION PADS INSTALLED AROUND BOTTOM CONE
RECLAIMING HOPPER WITH AERATION

Fig. 3 *Fig. 4*

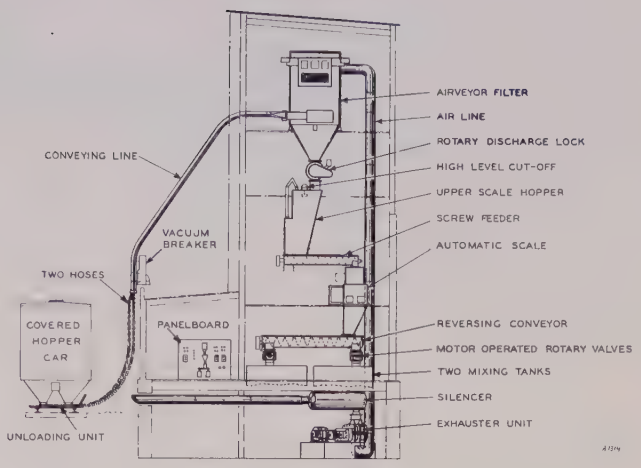

Fig. 5

hopper, either through mechanical or pneumatic means. From this weigh hopper, the clay is discharged into a mixing tank with a measured amount of water to make the required slurry. This is batch mixing.

With the dependability of modern transportation methods, the trend today is to unload clay direct from cars into slurry form, eliminating dry storage to a great extent. However how far this elimination can go depends on location of mill with respect to the mines, transportation facilities, and the substitution of sufficient slurry storage. Increased demands on a mill for coated stock caused a recent conversion to this type of operation, Fig. 5. Spray dried clay is received in 50-ton capacity covered hopper cars, divided into two sections. Unloading of the car is done by an Airveyor pneumatic system having a capacity of 25 tons per hour, through a covered hopper car unloading unit, two 5-in. hoses, an 8-in. conveying line, an Airveyor filter which separates the clay from the air stream and a 100-hp. exhauster unit.

From the filter, the clay is discharged into a surge hopper through a totally enclosed rotary discharge lock. The upper scale hopper, which acts as a surge hopper is equipped with a high level cut-off which automatically opens a vacuum breaker in the conveying line to stop conveying in the event clay is unloaded faster than the equipment following the upper scale hopper can take it away. A screw feeder feeds the clay from the upper scale hopper to a Class 50 Richardson automatic scale. This screw feeder fills the main scale hopper quietly and evenly. However, this screw feeder should be large and operate slowly so as not to aerate the clay further.

As in conveying and storing, here also special precautions are taken in the choice of weighing equipment. The scale hopper itself is stainless steel to provide a smooth inner surface. Also, this hopper is equipped with vibrators, operating whenever the discharge gate is opened, to make certain that all the weighed material is effectively discharged. Further

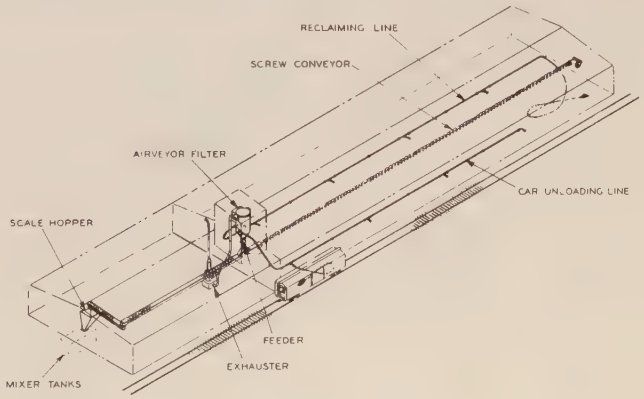

Fig. 6

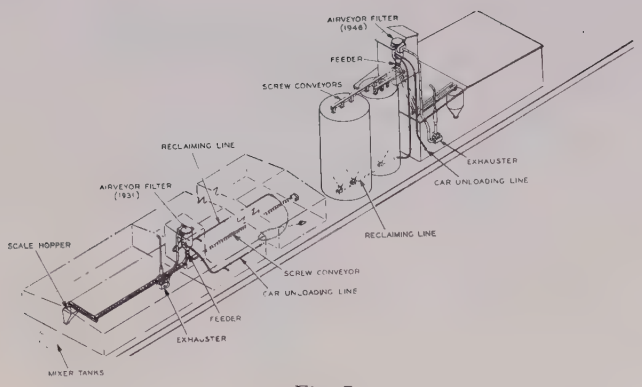

Fig. 7

precaution is made on the discharge gate. This gate is power operated and brush sealed so that no material can escape while the weighing is being made. However, when the discharge gate of this scale hopper is opened upon completion of each 250-lb. weighing, the clay is discharged quickly and completely.

From the scale, the clay is discharged to a surge hopper which, in turn, discharges to a reversible screw conveyer that feeds to either of two slurry mixing tanks. Because a definite amount of clay is required in each of these mixing tanks, the scale discharge is controlled by an electric counter that is set for the required number of discharges. Upon completion of that number, the scale is automatically stopped and conveying terminated.

A main control panel is used for the conveying equipment as well as the preparation and mixing of the slurry. Purified water is first metered into the twin tanks, and then the preweighed clay. A complete batch in each tank consists of 25,000 lb. of clay (or $^1/_4$-hopper car), mixed in the proportions of 10 lb. of clay per gallon of slurry.

Mixing of the slurry is accomplished by a propeller-type central mixing shaft combined with baffles built into the side of the tank. It takes approximately $^1/_2$ hr. to complete mixing a full batch to a slurry consistency of 70% solids. Slurry is then automatically withdrawn from the bottoms of the tanks and pumped a distance of approximately 100 ft. to storage. The entire operation, allowing time for each phase of the process from dry clay in cars to mixed slurry in storage tank, takes no more than 4 hrs., and last, but by no means least, by one man.

A Northern mill, through its expansion over the years, illustrates the trend in clay handling and storage. Prior to 1931, clay was entirely handled in bag form. Then, with savings possible in not only the cost of clay in bulk over bag, but also labor, the first bulk handling system was installed, Fig. 6. This installation unloaded clay from box cars (hopper cars were still a novelty) pneumatically at $7^1/_2$ tons per hour and delivered to a flat storage building. Distribution within the building was by an open type screw conveyer with the clay forming its own trough. The clay was reclaimed

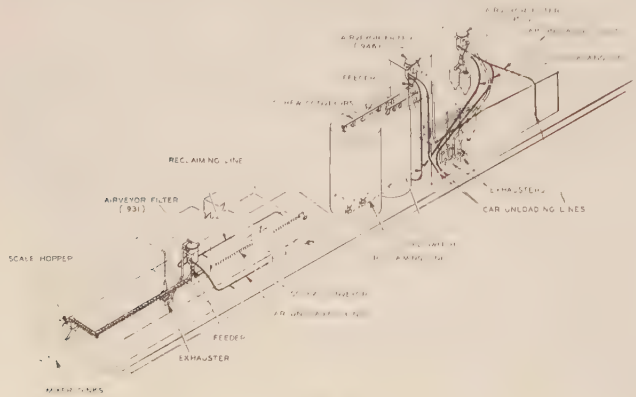

Fig. 8

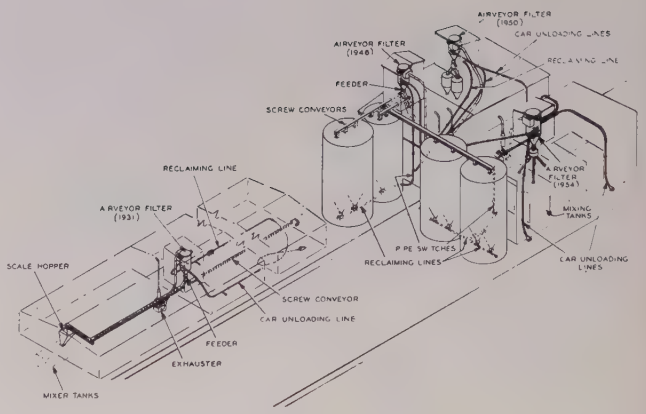

Fig. 9

pneumatically through the same equipment used for unloading, and then through another screw conveyer to a batch wehgh hopper and mixing tank.

To take care of additional clay requirements in 1946, two concrete stave vertical storage silos were erected together with additional batch mixing facilities, Fig. 7. A pneumatic conveyer, due to 15 years of excellent service on the original system, was chosen to again unload box cars and deliver to the storage silos. The same pneumatic system also reclaims the clay from the silos and delivers the clay to the batch weighing and mixing equipment. As additional paper machines were added and production increased, this system was hard put to maintain production schedules. So, further expansion of clay handling was needed. In 1950, an additional pneumatic system, also 8 to 10-ton capacity was installed to unload clay, this time, however, to go from cars directly to batch weighing and mixing equipment, Fig. 8. Here is the first attempt to go from cars direct to slurry. Two years later this system was extended to unload from additional car stations.

So far in this saga, all operations were tied in to batch weighing and mixing. In 1954, with production again on the rise, more efficient clay handling was needed. It was at this time that this mill conceived the idea of unloading clay direct from cars and delivering directly to slip mixing tanks, Fig. 9.

The building housing the slip mixing tanks was built with eight of these tanks, with each tank capable of holding a whole carload of clay. To meet this additional unloading capacity, the fourth pneumatic conveying system was installed. This system, designed to unload 20 to 25 tons of clay per hour, has unloaded as much as 195 tons of spray dried clay in 7 hrs. In the tanks, clay is mixed with water and pumped through a fine mesh screen into storage tanks. Next, clay is pumped to the coating preparation plant and blended with other ingredients to produce the final blending.

In conjunction with this slurry mixing plant, two additional concrete stave silos were erected to hold about 2000 tons of dry clay. Through additional screw conveyers, these silos are filled by the pneumatic system installed in 1946, allowing the high capacity system to service this enlarged slurry facility by unloading from cars direct and by reclaiming from these two new silos. This mill's wet storage capacity plus its huge dry reserve capacity means that, regardless of possible delays in transit (as when railroad equipment is stalled for any reason), slurried clay is instantly available. During the blizzards of 1958, for example, no slowdown caused by shortage of clay occurred.

When you design your clay handling facilities, first, check your supplier on the physical characteristics; second, decide either dry or slurry storage or both; third, determine mill requirements, and fourth, take advantage of the best material handling talent available, keeping in mind that the best isn't always the cheapest.

Presented at the 15th Engineering Conference of the Technical Association of the Pulp and Paper Industry, held in Jacksonville, Fla., Oct. 24–28, 1960.

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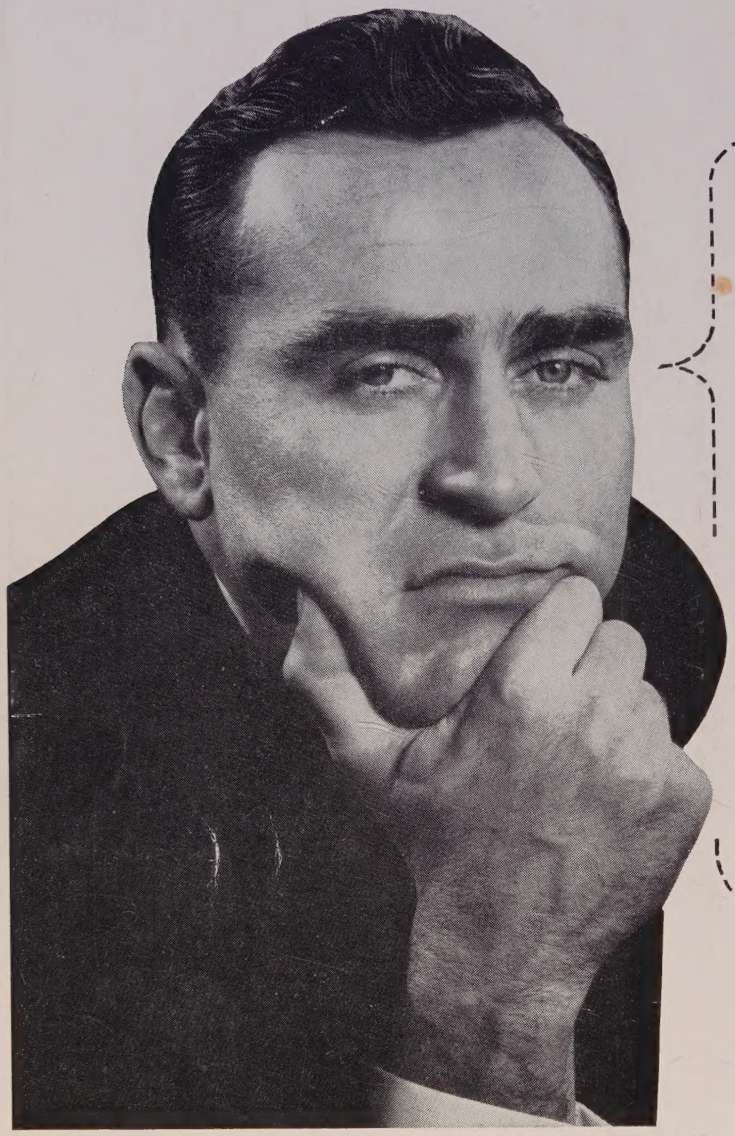
Thinking of coating or filling with clay?



Should we use a trailing blade... or an air knife?

Maybe it should be a roll coater... or a reverse roll?

What about a size press?

Double coating? Simultaneous or successive?

On or off the machine?

Wet or dry storage?

Fill at the secondary headbox?

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